



Fire!

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Black holes

Photographing cosmic monsters

Dinosaurs

How their killer was unmasked

FOCUS

SCIENCE AND TECHNOLOGY

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BREAKTHROUGHS

OF

2013

Top experts predict the discoveries that will shape the future



MAGGIE ADERIN-POCOCK
on space technology



JESSICA GREEN
on invisible ecosystems



JIM AL-KHALILI
on quantum biology



MARK MIODOWNIK
on self-healing buildings



SHEILA NIRENBERG
on rewiring the brain



ANDREA SELLA
on new energy sources



CRAIG VENTER
on 3D biological printers



STEPHEN WOLFRAM
on artificial intelligence



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WELCOME TO FOCUS



PERSONAL SATELLITES, GENETIC data that can be sent by email and computers that really understand you. Those are just some of the amazing breakthroughs that science could make in the next 12 months. For the second year running we've tracked down the world's top experts to bring you the very latest developments from the cutting edge of science. These breakthroughs may

well bequeath us useful inventions, so it's entirely fitting that BBC Two is running a year-long season called *The Genius Of Invention*. Our 'Watch' guide on p100 will keep you up to date with individual programmes during the year.

Well worth watching on TV, whether you're young or not so young, are the celebrated Royal Institution Christmas Lectures. We caught up with this year's presenter, the 'Modern Alchemist' Peter Wothers, and were given special access to the RI's famous theatre. See p44 for more.

Starting the New Year in style on BBC Two is *Stargazing Live*, and to celebrate we decided to take a look at a truly mind-blowing astronomical topic – a telescope that will capture an image of a black hole. Heather Couper has the story on p57.

Finally, let's all hope the financial outlook is sunnier this year than last. But if economists want any tips, Robert Matthews will oblige on p49. He reveals how they could save the world from disaster with just one equation. It's the least we can do.

Graham

Graham Southorn, Editor

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APPEARING IN THIS ISSUE...



Maggie Aderin-Pocock

Formerly the head of the optical instrumentation group at satellite builder Astrium,

Maggie makes regular appearances on BBC TV. Her shows include *Do We Really Need the Moon?* and *In Orbit: How Satellites Rule Our World*.



Jessica Green

Associate Professor Green is director of the Biology and the Built Environment Center at the

University of Oregon. She's an ecologist whose research asks questions about patterns in the distribution and abundance of species.



Craig Venter

The founder of the J Craig Venter Institute is a leading biologist best known for being one of the first

to sequence the human genome and making the first cell with a synthetic genome. His research involves creating synthetic biological organisms.



Stephen Wolfram

Stephen is the chief designer of the Wolfram Alpha 'answer engine', produced by his

company Wolfram Research. In the 1980s, he specialised in the study of cellular automata and is the author of *A New Kind Of Science*.



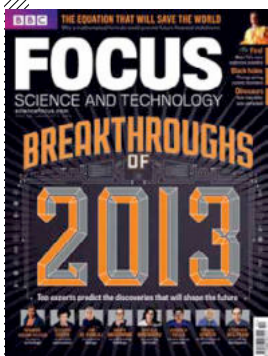
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BREAKTHROUGHS OF 2013

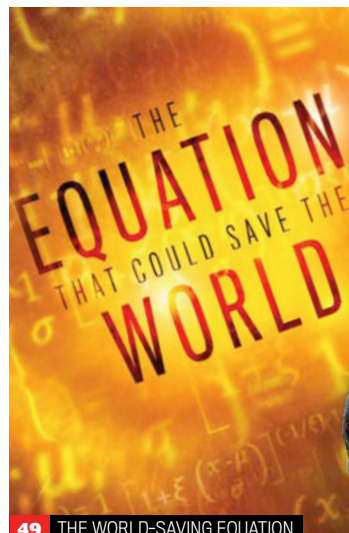
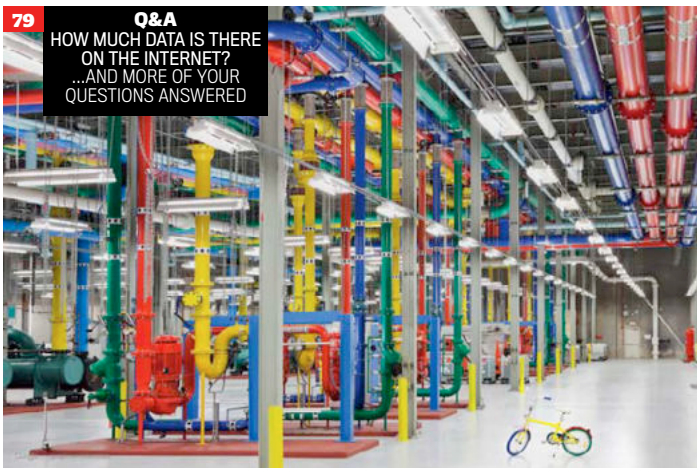
The biggest names in science take you on a tour of the laboratories they think will change the world in the year ahead



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MegaPixel

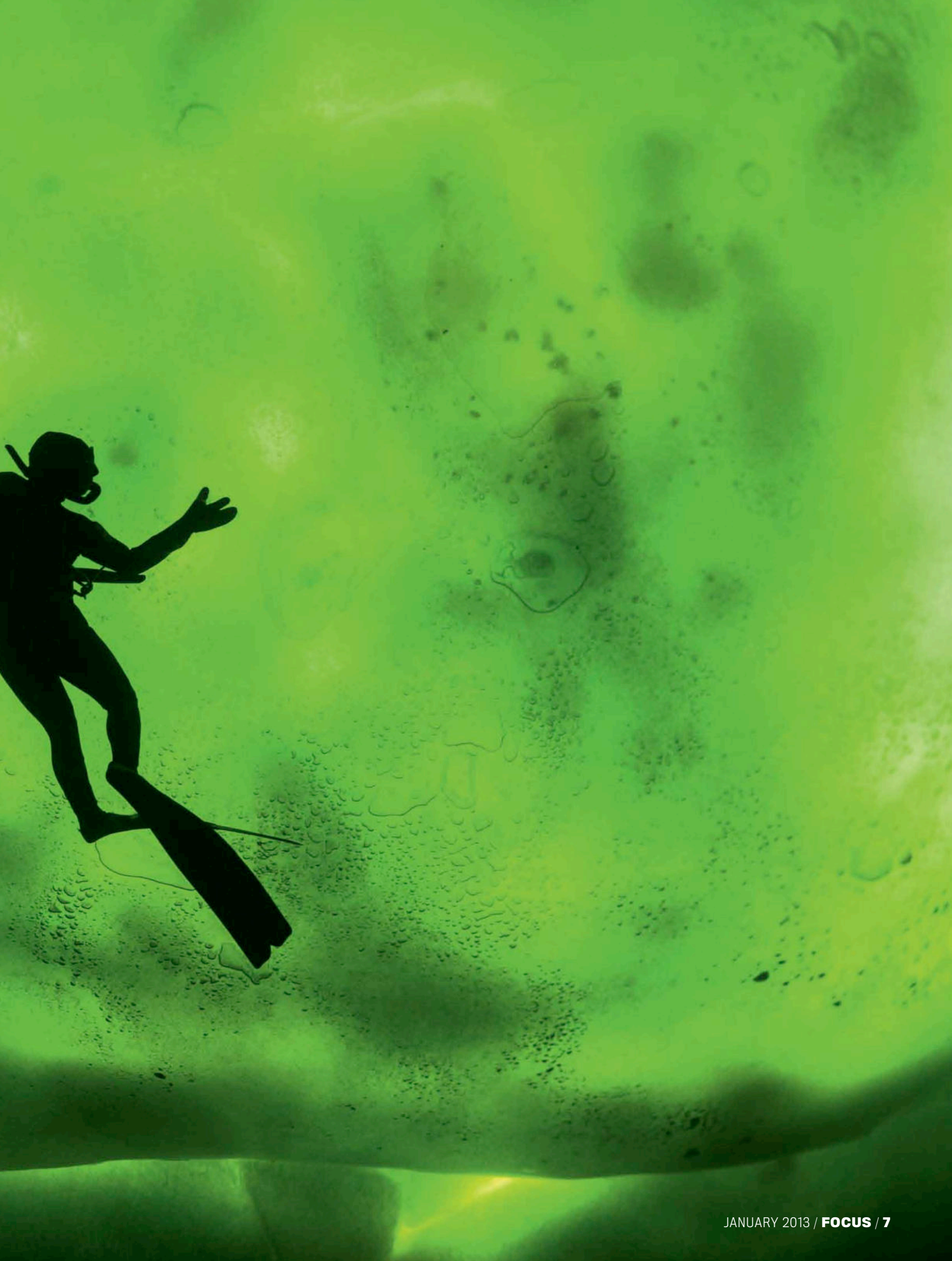
Underwater aurora

A DIVER SWIMS in Russia's White Sea, silhouetted against a glowing green aurora seen through a thick layer of ice. Although the aurora is visible in the icy depths of this sea within the Arctic Circle, its origins lie in the Sun.

As fusion occurs within our star, it spews out high-energy particles such as electrons and protons. Some of these will encounter Earth's magnetic field, causing it to release high-energy electrons. These transfer their energy to oxygen and nitrogen atoms and molecules in the atmosphere, making them excited. When they return to their normal state, they release light. The colour of an aurora depends on which type of atoms are being struck and at what altitude. This green glow would have resulted from impacts between electrons and oxygen atoms 100-300km up in the atmosphere.

"Aurorae are caused by an increase in solar activity, and we are just about reaching the maximum in activity levels," says Professor Louise Harra, a solar physicist at University College London.

PHOTO: GEORGE KARBUS/SOLENT





Carrion a backpack

IT IS PERHAPS one of the most grizzly sights the insect world has to offer – an assassin bug carries victims around for all to see. This macabre backpack isn't the bug's attempt to show off its killing prowess, but a tactic it employs to avoid becoming prey itself.

Found all around the world, the insect – which belongs to the genus *Acanthaspis* – uses sharp mouthparts to pierce ants before injecting digestive enzymes. These liquefy an ant's insides, enabling them to be sucked out.

Once devoid of its innards, an ant is loaded up with its fellow victims, and held together with a sticky glue secreted from the insect's back. "It's really quite comical, a tiny bug crawling around with a pile of dead ants on its back," says Professor Simon Pollard, an entomologist at the University of Canterbury in New Zealand.

The pile of ant bodies disguises the assassin bug from predatory jumping spiders. "The predator still notices it, but doesn't recognise it as prey," says Pollard.

PHOTO: CATERS NEWS







+ MegaPixel

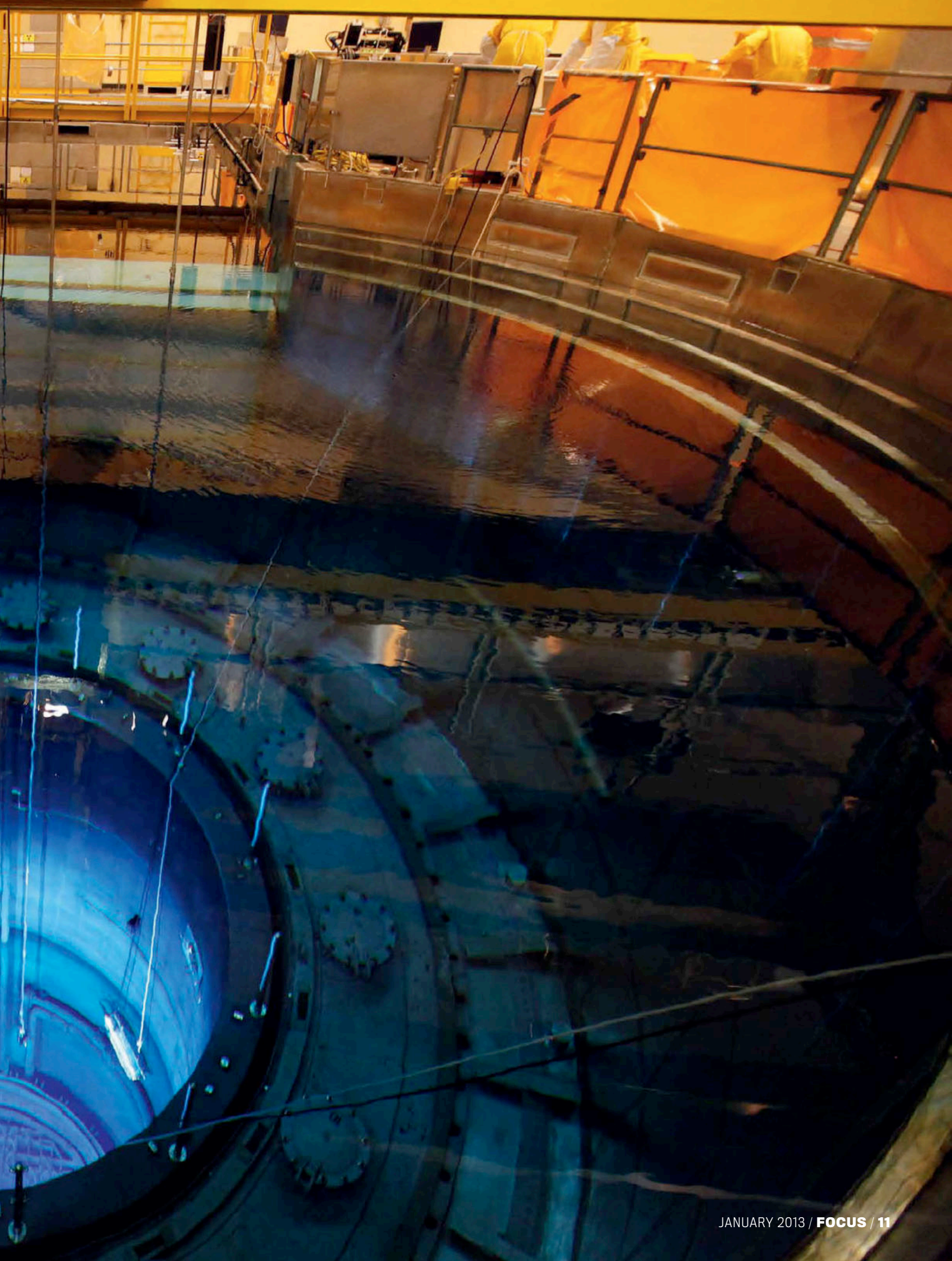
The core

IT COULD BE the set from a Bond film – a glowing, radioactive pool into which 007 will be slowly lowered. But this is the reactor core at the Mühleberg Nuclear Power Plant in Switzerland, open for an annual inspection. The blue hue of the water surrounding the fuel rods is due to a phenomenon known as Cherenkov radiation.

As the products of nuclear fission – such as caesium-137 – decay, they release electrons that travel at high speed. These tear through water molecules, leaving them in an energetic state which they shed by emitting light. But because the electrons are travelling faster than the speed of light in water, light waves bunch up into a shock wave, like the sonic boom created by the sound waves of supersonic jets. The result is a bright blue glow: Cherenkov radiation.

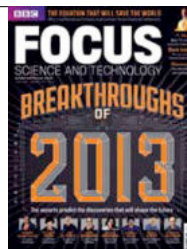
“The intensity of the glow tells you how many fast particles are being emitted and that tells you how much radioactive fission fragment material there is in the fuel,” says Professor Paddy Regan, a nuclear physicist at the University of Surrey.

PHOTO: REUTERS



REPLY

Your opinions on science, technology and our magazine



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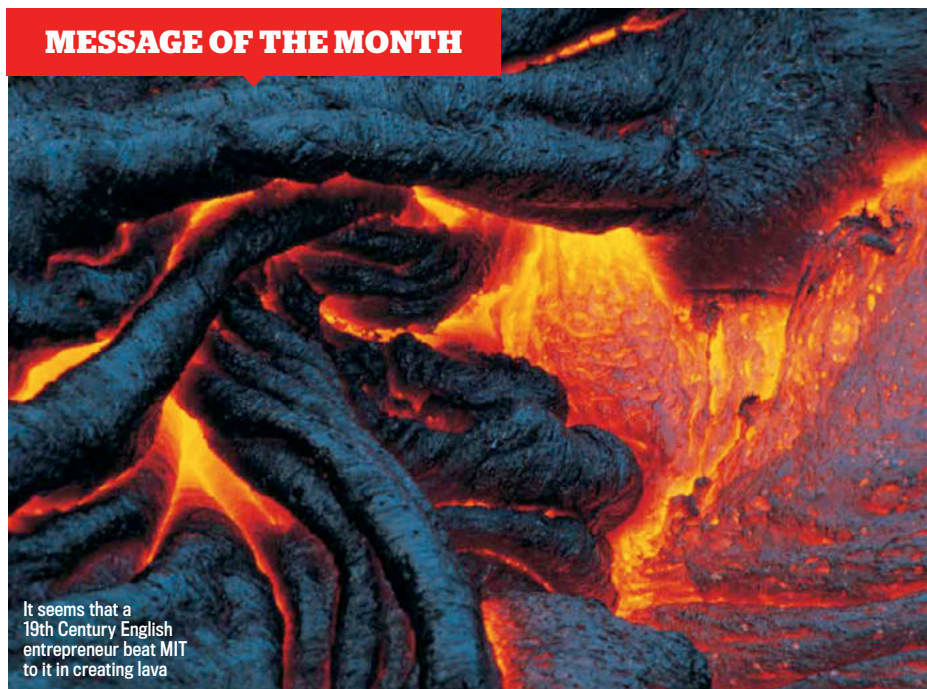
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Letters may be edited for publication

MESSAGE OF THE MONTH



It seems that a
19th Century English
entrepreneur beat MIT
to it in creating lava

All you need is lava

With reference to the November issue and the question on page 92, 'Could molten lava be made in a lab?', I would like to point out that this was achieved in 1861 in the Black Country, long before MIT was founded!

In 1851, Henry Adcock entered into an arrangement with Chance Bros of Smethwick to use a reverberating furnace to melt the local olivine dolerite form of basalt, from the Rowley Hills, which form a prominent geographical feature near Dudley. Adcock melted the basalt, known locally as Rowley Rag, and cast a variety of articles, such as slabs for steps and tables, window-heads and sills, mantelpieces and doorways. Unfortunately, the cost of fuel for melting

the basalt proved uneconomic despite the durability of his products. By 1866, a few examples were all that remained: a house in Handsworth, some terraces in Aston Park and Wolverhampton, and an old vestry in Edgbaston.

Prior to Adcock's enterprise, Sir James Hall (1761-1832), a friend of Lavoisier and James Hutton, also experimented with melting lava. The apparatus he used, such as his crucible and specimens of marble he produced from chalk, are in the Geological Museum, London. It is incredible that they were able to do this without modern heating methods and apparatus. **Gordon Hensman, chairman of the Black Country Geological Society**

Mindgames

I was amused by the trick question about two planets orbiting 100 and 400 miles respectively from the centre of the Sun (December, p127). May we expect an article about these two planets orbiting in what seems to be the precise opposite of the Goldilocks zone? A most entertaining and enjoyable 'Mindgames', as always.

Jill Wilson, Chipping Campden

Turbine tech

'Road to the future' (December, p60) was a fascinating article. I was intrigued to see the motive power for the air car relies on 200-year-old technology in the form of a double expansion reciprocating engine! Would a turbine not be more efficient?

After all, ship builders from the turn of the last century thought so – have a look at Charles Parsons' ship Turbinia, which so rattled the British fleet at Spithead in 1897, attaining a speed of 34 knots.

Andrew Mirylees



Turbinia, the fastest ship of her day, now lives at the Discovery Museum in Newcastle

Birds vs dinosaurs

As a parent of a dinosaur-obsessed preschooler, I found October's subscriber feature on dinosaur palaeontology fascinating. However, to my mind the article was missing comment on two important areas. If, as the author suggests, modern birds are the current incarnation of dinosaurs, does this mean that the mass extinction of dinosaurs was not as extreme as supposed? Also, what happened to the pterosaurs and plesiosaurs? Did they evolve, or die out?

Mel Ealing, Epsom



**Write in
and win!**



Gordon wins a copy of *The Science Magpie* by Simon Flynn (Icon Books, £12.99). Send us your views to win next month's prize.

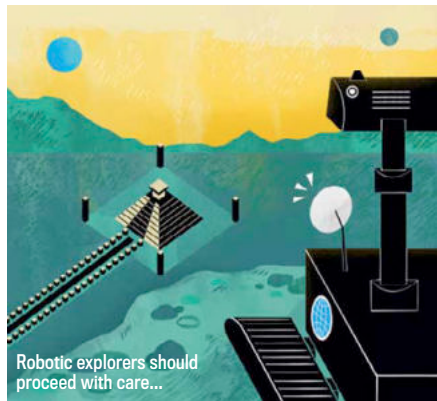
Dr Darren Naish replies:

Birds are indeed the only dinosaur lineage that survived the mass extinction event at the end of the Cretaceous, 65 million years ago. Given that all other dinosaur groups did become extinct at this time, it was still a devastating event for dinosaurs as a whole. Furthermore, numerous other animal groups – the pterosaurs and plesiosaurs, and others – became extinct at the same time. Birds made it through.

Baxter's best

As much as I've read and enjoyed *Focus* for a long time, I've never felt enough reason to write in. Until now. Stephen Baxter's 'Into the future' column in the December issue was such a great little piece. It cheered me up no end, especially the last sentence.

Mark Fagan



Taking a swipe

I've been a *Focus* reader for many years. Recently I have managed to sign up to the iPad edition after some technical difficulties and I have to say I love it – suddenly reading *Focus* has become even more exciting! It's turned into a real journey of discovery, full of hidden treasures and surprises, as you never quite know what extra features you will find behind the next swipe.

I also really like the new look. The little arrows guide you through the magazine, and the general layout is now a lot cleaner and more organised, making the articles easier to read. Thank you for doing such a great job – I hope you will continue publishing *Focus* for many years to come!

Isabelle Rutkowski-Stepien

Oops!

The caption on p98 of November's 'How do we know?' article should have read "In the top diagram, Earth is further from Jupiter" and not "nearer to Jupiter".

YOUR COMMENTS ON TWITTER

On twitter.com/sciencefocus we asked:

What breakthroughs would you like scientists to make next year and why? #2013breakthroughs

@clarsquirrel cure cancer. Does it really need an explanation? I'd also like them to invent a Tardis for me!

@highlandgirl for scientists to find a way to make us immortal...

@AgataPokutycka slow the time so it does not run so quick... it would give me more time with the kids

@MarkColtman alternative energy which would be widely accessible to everyone so we can stop drilling

@JudeVFR400 a cure for MS and other neurological disorders would be nice. Why? I have MS. It's boring.

@koey666 find a cure for depression – make the world a happier place!

@greigo_uk better spaceships so we can travel the Universe and meet aliens

@NickAstronomer positive detection of a life-bearing atmosphere on an exoplanet... or life on Mars

@_NaomiK_ a tablet like the one in Limitless because if I could access 100% of my brain, I would be a genius!

@angoraferrets time travel. That would come in handy for lottery numbers

@NoodleNumpty lifespan is increasing, how about a cure for dementia-related diseases to ensure quality in later years?

@lisanorfolk as my daughter has a congenital heart defect I would love to see a cure for that

@suenatal develop highly efficient propulsion system for space vehicles to allow faster and further space travel

@edwardgoat nuclear fusion to last 10x longer than it currently does, that would be a great breakthrough

@SWIFTagent24 a clean source of energy that can easily replace petrol/diesel with the same results

Carry on the conversation using the hashtag #2013breakthroughs

FOCUS

SCIENCE AND TECHNOLOGY

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Soil similar to Hawaii's is found by NASA's Curiosity rover on the surface of Mars

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Do 'smart pills' give students an unfair edge at exam time?

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The hunt for ancient life in an Antarctic subterranean lake

p23



THE BIG STORY

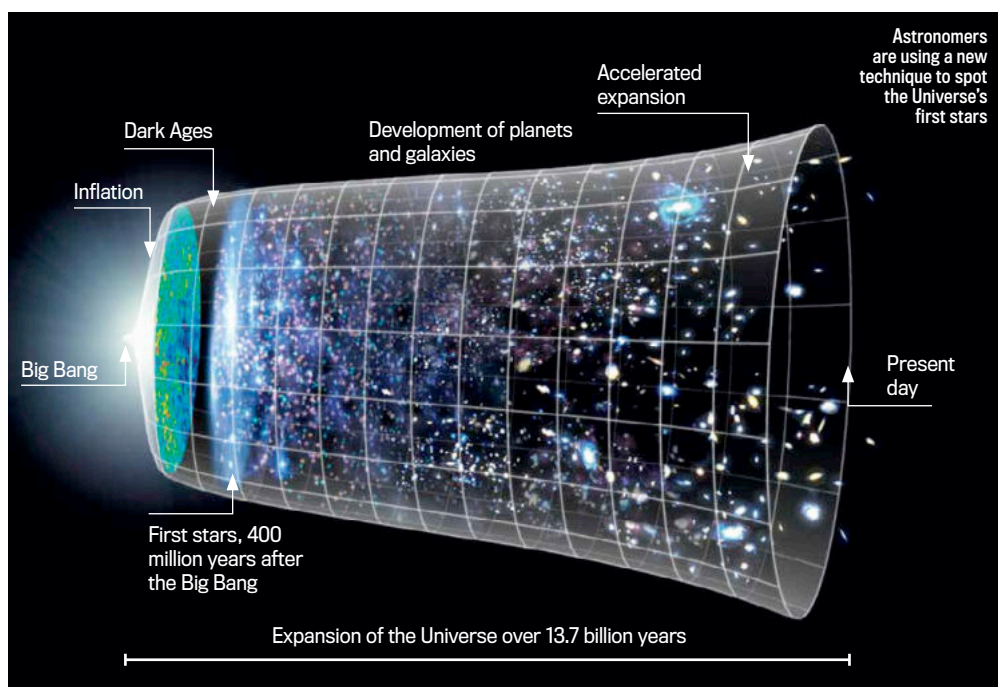
First ever stars are resurrected

Telescope reveals some of the earliest suns, and sheds light on the Universe's formative years



Gamma rays emitted by black holes inside 'blazar' galaxies were key to the new study

PHOTO: NASA



→ LIGHT FROM SOME of the very first stars that formed – which have long since fizzled out – has been measured for the first time. The achievement provides an insight into what happened just after the Big Bang, in an era that astronomers know as the Dark Ages.

For some time, it's been known that 13.7 billion years ago, about 400 million years after the Big Bang and as the superheated particles it created cooled and formed atoms, the Universe went dark. Some time later, the earliest stars ignited. But exactly when these first stars formed and what the Universe looked like at that time has been far from clear – even the most powerful telescopes are unable to peer back that far.

Now an international team of more than 200 astronomers has been able to measure some of the first stars indirectly, discovering that they appeared no more than 500 million years after the Big Bang. Dr Marco Ajello, an astrophysicist at Stanford University in California, and his team used an ingenious technique. Light from all the stars that ever shone – including the very first – still echoes around the Universe as extragalactic background light (EBL). To measure this,

they used NASA's Fermi Gamma-ray Space Telescope to study 'blazars' – galaxies that appear incredibly bright thanks to gamma rays, the most energetic form of light, that shoot from their black holes.

These gamma rays collide with the background starlight and lose some of their energy. The team studied 150 blazars between 0.4 and 9.5 billion light-years away. Knowing how bright each of them should have been, and how far away they are, they could work out how much a blazar's light had been dimmed – and therefore how thick the EBL is. By subtracting the light from the younger galaxies, it was possible to determine how much light there was in those first stars.

"Viewing these stars directly is currently impossible. But the James Webb Space Telescope, when it launches in a few years, may be able to see the first galaxies," says Dr Ajello. The thickness of the EBL fog showed Dr Ajello's team that each star in the early Universe would have been separated by more than 4,000 light-years. In the Milky Way today, the average separation is about five light-years.

Further results from Fermi may pinpoint more precisely when the first stars came to life.

PAUL SUTHERLAND

ANALYSIS

Steve A Eales



Professor at Cardiff University's School of Physics and Astronomy

“ ASTRONOMERS HAVE long wanted to learn more about the earliest days of the Universe. Innovative techniques now being used to analyse extragalactic background light or identify early galaxies are helping peel back the layers of cosmic history, and taking us closer than ever to the Big Bang.

One thing we have been keen to figure out is how much energy has been produced by all the stars in all the galaxies over the whole of time. We've tried to do this before by taking photos of deep space, counting all the galaxies and measuring how much radiation is coming from them all. The trouble was you were never quite sure, when adding it all up, whether you were missing objects that were too faint to pick out, but which might be contributing a lot of radiation.

Another riddle is that there is a huge amount of gas in the Universe, yet it appears that very little of it – around five per cent – has been turned into stars. We wondered whether we were missing a lot of stars that were possibly too faint to detect in intergalactic space.

This new method of working out the total radiation via the cosmic fog shows we weren't missing anything after all. It helps get rid of a lot of our uncertainty about the Universe. **”**



TIMELINE

Understanding the Universe's furthest reaches

1908

Henrietta Leavitt finds a way to measure the intrinsic brightness of Cepheid variable stars, and so use them as 'standard candles' to measure distances.

1925

Edwin Hubble shows that there are many galaxies in the Universe. It was previously believed that the Universe was one vast sea of stars.



1938

Type-I supernovae are identified by Walter Baade as another form of standard candle that can reveal the distances of remote galaxies.

1958

Allan Sandage estimates the rate of expansion and age of the Universe, showing it to be 7-13 billion years old. Today it is known to be 13.7 years old.



2011

A gamma-ray burst from a star 13.14 billion light-years away in the final days of its life becomes the most distant single object spied by a telescope.

2012

Using NASA's Fermi space telescope, astronomers measure light from some of the earliest stars, formed just 500 million years after the Big Bang.



WHAT DO YOU THINK?

Let us know your thoughts at facebook.com/sciencefocus

1 MINUTE EXPERT

Telomeres

What are they?

Protective caps that sit on the end of chromosomes, preventing the genes towards the end of one of these strings of DNA from degenerating.

Why are they in the news?

University of East Anglia biologists have been watching what telomeres get up to in wild birds. Theirs is the first study to measure telomeres across the entire lifespan of a wild animal. They found that telomere length is a good predictor of how long an animal has to live – better even than knowing its age.

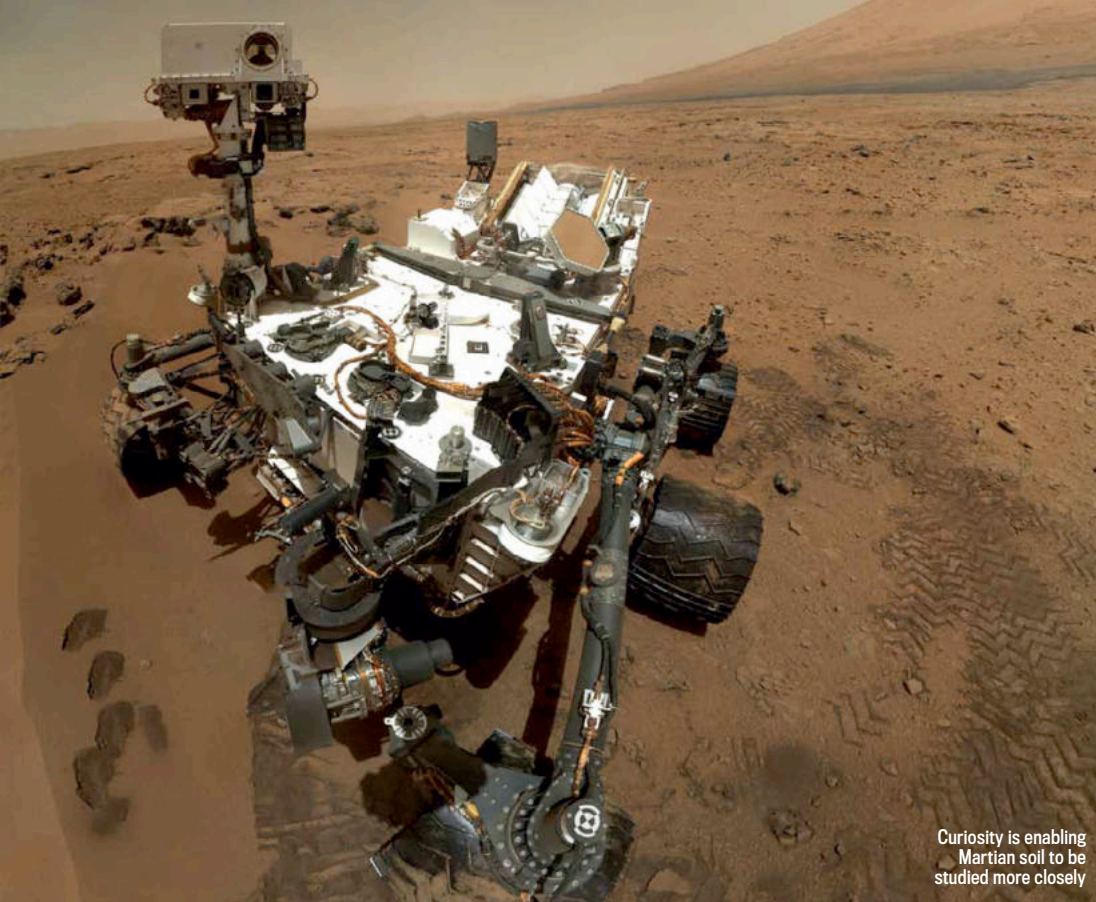
How did they find this out?

For two decades, they collected blood samples from Seychelles Warblers on Cousin Island in the Indian Ocean, to get DNA samples and measure telomere length.

What happens to telomeres?

Over a bird's lifetime they get shorter and shorter, leading eventually to the bird's death, but the rate of shortening isn't the same for every bird. In birds facing more 'biological stress', such as having a tougher time finding food, the telomeres get shorter more rapidly. It's because telomeres shorten at different rates in different birds that they're so useful for predicting longevity.

ANDY RIDGWAY



Curiosity is enabling Martian soil to be studied more closely

Space exploration

Mars: a bit like Hawaii

PATCHES OF SOIL on the Red Planet show a striking similarity to the volcanic soils that are found in Hawaii, analysis carried out by NASA's Mars rover Curiosity has revealed.

Instruments installed on the car-sized vehicle are allowing Martian soil to be analysed in unprecedented detail. Because the mixture of minerals present reflects the conditions under which they formed, studying it can provide new insights into Mars's past – and an indication as to whether conditions were ever suitable for life to appear.

A recent sample collected by Curiosity from the Gale Crater contains minerals such as feldspar, peroxenes and olivine – just like

the soils on Hawaii. Unlike a several billion-year-old rock first sampled by Curiosity, which indicated the presence of flowing water in the past, this sample reflects more modern processes and shows no sign of water having been present.

Curiosity's Chemistry and Mineralogy (CheMin) instrument was used to analyse the sample. It uses X-ray diffraction, in which a mineral's internal structure is revealed by how its crystals interact with X-rays.

The mineralogy at this patch of sand and dust within the Gale Crater – named Rocknest by the Curiosity team – had been anticipated by researchers. But things should get particularly interesting when the rover reaches its ultimate destination within the Gale Crater, the 5km-high Mount Sharp.

"We believe it contains a record of the very interesting part of early Mars history when conditions were suitable for the origin of life – warm, wet conditions when abundant water was present on the surface," says Blake.

KELLY OAKES

WHO'S IN THE NEWS?

Professor Gerald Crabtree

Geneticist at Stanford University in California

What did he say?

That human intelligence peaked over 2,000 years ago and has been ebbing away since. He wrote in the journal *Trends In Genetics*: "I would wager that if an average citizen from Athens of 1000BC were to appear among us, he or she would be among the brightest and most intellectually alive of our colleagues and companions."

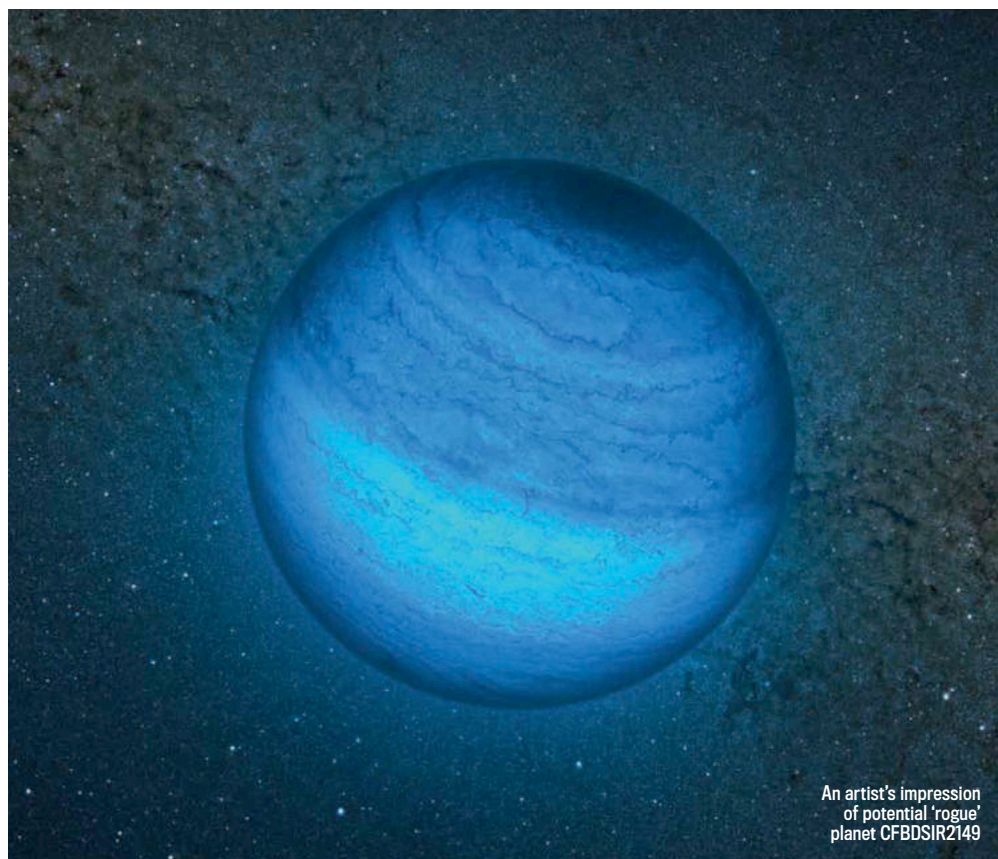
Why did he say this?

Prof Crabtree argues that for most of our evolutionary history, humans lived off our wits as hunter-gatherers. But when we started living in cities and developing agriculture, genetic selection for intelligence would have stopped. This would allow mutations in genes that have a negative impact on our brain-power to remain.

Has it caused a stir?

Crabtree's idea has been met with some scepticism. Oxford University anthropologist Prof Robin Dunbar told *The Telegraph*: "Prof Crabtree takes the line that our intelligence is designed to allow us to build houses, but... in reality what has driven human and primate brain evolution is the complexity of our social world."





An artist's impression
of potential 'rogue'
planet CFBDSIR2149

Astronomy

Wandering neighbour looks like a rogue world

WHAT APPEARS TO be a planet wandering through space without a star to corral has been spotted just 100 light-years from our Solar System. If the object is confirmed as a planet, it would make it the closest 'rogue world' to Earth.

Aside from its proximity to us, this candidate planet, named CFBDSIR2149, is particularly interesting because it appears to be drifting through space with a stream of young stars known as the AB Doradus Moving Group. This would mean the object – found by a French-Canadian team using a telescope in Hawaii – is also likely to be young. Potential rogue planets have been discovered before, but without knowing their ages it has not been possible to discern whether they are indeed rogue worlds, or much older brown dwarfs – failed stars that lack the bulk to trigger nuclear reactions.

If it is a rogue world it would have formed in a solar system before being booted out. But even if it's a brown dwarf, it is still interesting. "These objects can help us understand more

about how planets may be ejected from planetary systems, or how very light objects can arise from the star formation process," says Dr Philippe Delorme at the Observatoire des Sciences de l'Univers de Grenoble.

The fact that this object is going it alone means it can be characterised in better detail than 'normal' planets. "Looking for planets around their stars is akin to studying a firefly sitting 1cm from a distant, powerful car headlight," says Delorme. "This nearby, free-floating object offers the opportunity to study the firefly in detail without the dazzling lights of the car messing everything up."

The detailed analysis, made using the European Southern Observatory's Very Large Telescope, shows this world is between four and seven times the mass of Jupiter and has a temperature of 430°C. The characterisation of this planetary candidate could act as a benchmark for understanding similar objects that are likely to be discovered using more powerful imaging systems in the future.

ANDY RIDGWAY



DIGITAL WORLD

Science on the web

ONEZOOM

www.onezoom.org

This tree of life might look a little lopsided, but zoom in and you'll find it has hidden depths. The trunk represents the first life on Earth, which splits into branches over time. Each species gets a leaf. The fractal-like structure means the tree can hold more information without overcrowding.

SPOT THE STATION

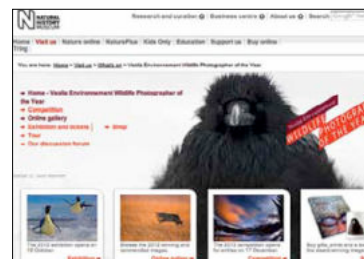
spotthestation.nasa.gov

The International Space Station is the third brightest object in the sky after the Sun and Moon, making it easily visible from anywhere on Earth. You just have to know when to look up, which is where this site from NASA comes in handy. Tell it where you live and it will send you an email or text a few hours before the ISS passes overhead.

WILDLIFE PHOTOGRAPHER OF THE YEAR

nhm.ac.uk/wildphoto

The internet is notorious for its endless cat pictures, but this online gallery of pictures selected for the Wildlife Photographer Of The Year exhibition is in a whole other league. Be warned, though: there's nothing cute or cuddly about cheetah cubs on a hunting lesson!



The Wildlife Photographer Of The Year site is full of awesome images of the animal world

THE HIDDEN LIFE OF THE CELL

secret-universe.co.uk

Our bodies contain trillions of cells, yet we know surprisingly little about them. This site shows you what we do know by taking you on the same journey a virus undertakes, going beneath a cell's surface down to its nucleus.

KELLY OAKES

GRAPHIC SCIENCE

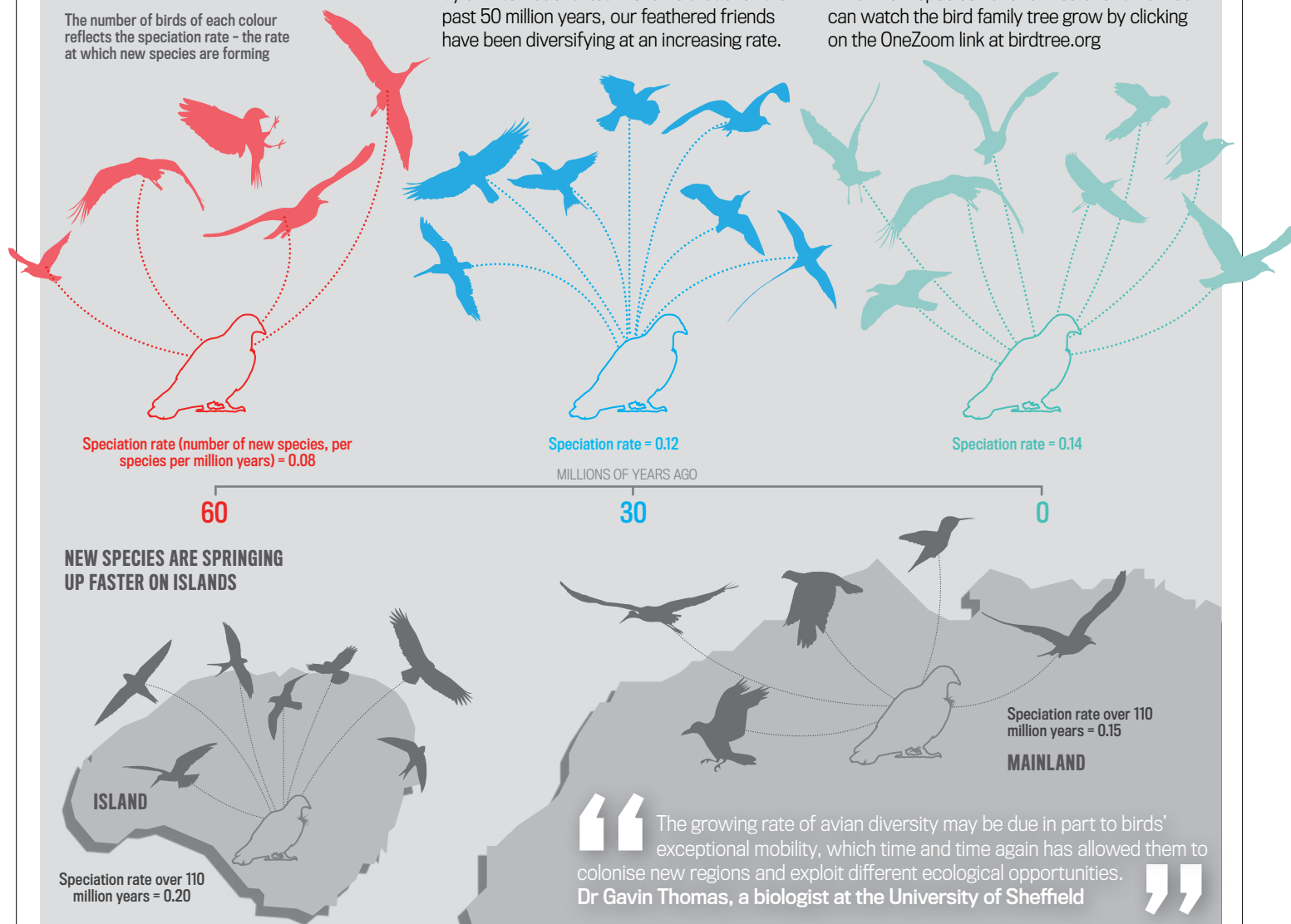
Seeing research differently

The number of birds of each colour reflects the speciation rate – the rate at which new species are forming

BIRD DIVERSITY IS ACCELERATING

In most groups of animals the rate at which new species form has declined over time, but with birds it's a different story. New research by an international team shows that over the past 50 million years, our feathered friends have been diversifying at an increasing rate.

The biologists used fossil and DNA data to produce a 'family tree' of avian life, which includes all 9,993 species alive now and shows where and when new species have arisen. They were then able to calculate the rate at which new species have formed over time. You can watch the bird family tree grow by clicking on the OneZoom link at birdtree.org



NEWS IN BRIEF

1,000 genomes mapped

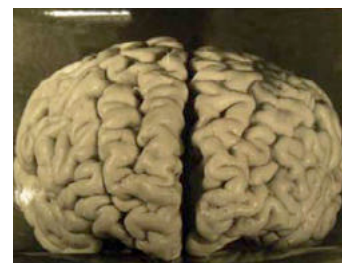
• The DNA sequences of over 1,000 people from 14 countries have been published – the largest inventory of human genetic variation to date. The 1,000 Genomes Project will enable geneticists to investigate variation between countries. Researchers are also combing the results to work out which genetic variations are responsible for disease.

LEDs boosted by fireflies

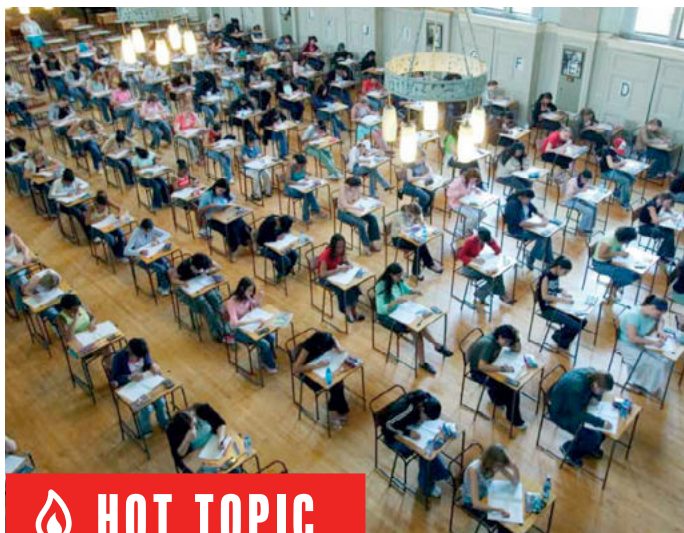
• Future LEDs could shine brighter thanks to a piece of design seen in the firefly's tail. A team at the Korea Advanced Institute of Science and Technology examined the firefly's light using an electron microscope and found its outer layer to be ordered like rows of crops in a field. When the patterns were reproduced on an LED lens, more light was transmitted.

Secrets of Einstein's brain

• Albert Einstein's mental agility may have been partly due to an unusually complex pattern of convolutions in his prefrontal cortex. These wrinkles would have given this region, important for abstract thinking, a large surface area. A US research team spotted the convolutions in photos taken by pathologist Thomas Harvey.



Einstein's prefrontal cortex was more complex in structure than most people's



HOT TOPIC

Is taking a 'smart pill' to boost exam performance an unfair advantage?

➔ SCREENING TO DETECT students taking drugs which improve their cognitive performance could become necessary, says University of Cambridge neuroscientist Professor Barbara Sahakian. While the university currently has no plans to start drug tests, Sahakian says they may be required in future if cognitive enhancers start presenting a significant problem.

Sahakian was speaking at the launch of a report by several organisations, including the Royal Society, entitled *Human Enhancement And The Future Of Work*. It states that in the

US, an estimated 16 per cent of students are taking cognitive enhancers such as Ritalin, which can improve short-term memory, and Modafinil, which can improve planning. One survey of Cambridge students found that 10 per cent admit to using cognitive enhancers to help with their work.

The Royal Society report states that in the future, pharmacogenomics – which studies the effect of an individual's genes on their response to drugs – may be used to determine which individuals will benefit from specific cognitive enhancers.



WHAT DO YOU THINK?

Let us know your opinions at twitter.com/sciencefocus using the hashtag #hottopic, and facebook.com/sciencefocus

Your Tweets and Facebook posts



Jules Conner: Would you then have to take drugs for your entire academic career to ensure you could carry on meeting your suddenly enhanced potential?



Simone Santos: They drink to party (alcohol = depressant) and take stimulants to enhance test results. Good luck to them when they're 40!



Antony Ingram: 'Unfair advantage' implies exams are about competing with peers, rather than knowledge. That's the bigger problem, really...

WHAT THE PAPERS SAY

HENRY GEE

New research from leading science journals



Thank little old ladies for your big brain

C OUSIN LUCY, UNCLE Fred... the list is endless. But I hope you didn't forget to get something nice for grandma this Christmas, because if it weren't for grandma, there'd be no you. And not just in the obvious sense. Evolutionary theory suggests that the evolution of grandmothers was crucial to the origin of human beings.

How so, I hear you cry as you search for a tablet computer with apps for knitting patterns?

Most animals live, reproduce and die. Few are the creatures that live any significant time after reproduction ceases. We are the exception. Women go through the menopause in middle age, with decades left to live. How can evolution tolerate creatures that hang on without making any effort to pass on their genes?

Ah, but they do – by helping their own daughters raise grandchildren. Grandmothers take older children off their mothers' hands, enabling them to have more babies more frequently. But that can't happen unless females live longer after the menopause. So what prompted the increase in female longevity in the first place? Was it the evolution of

large brains? Human babies are born with such large heads that their bodies are, when compared with apes, premature. This situation might favour the evolution of a cadre of post-reproductive females to help hard-pressed mothers cope with these big-brained, but helpless babies.

A surprising result comes from the first formal test of grandmothering. It shows that grandmothering itself leads to greater postmenopausal longevity, without any contribution from large brains or any other feature of biology or social organisation.

In their model, Kristen Hawkes of the University of Utah and her team started by comparing female fertility in humans and other apes. It turns out that both ape and human females can have babies into their forties. But after that, ape females tend to grow old rapidly, whereas human females live to a ripe old age. Modelling shows that in those ape societies that have even a tiny amount of grandmothering, longevity increases markedly, leading to more grandmothering, which leads to greater longevity, and so on. The more post-reproductive females there are, and the longer-lived they are, the more other benefits will flow – the benefits we associate with human beings, such as complex societies, the transmission of knowledge and the large brain.

It seems, therefore, that the roots of humanity lie with the human tendency to produce little old ladies. So, if you did forget to buy a seasonal gift for grandma, make sure you remember her birthday, okay?

Henry Gee is a palaeontologist and evolutionary biologist, and a senior editor of the journal *Nature*

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PATENTLY OBVIOUS

Inventions and discoveries that will change the world with James Lloyd



Smart windows to keep buildings cool

KEEPING BUILDINGS WARM in winter and cool in summer is an expensive business. But Japanese electronics giant Sharp says its 'smart windows' will help to keep costs down by actively controlling the amount of the Sun's energy coming in.

Sharp's patent application states that current window technology provides either fixed or electrically-controlled management of the amount of light travelling through a window. But if glass is coated with a special material known as a cholesteric liquid crystal, a window can be

manufactured that will change its properties automatically.

When it's chilly outside, the liquid crystal lets through radiation from both the visible and near-infrared parts of the Sun's electromagnetic spectrum, allowing the building to be heated. But when it gets warmer, the molecules spontaneously realign and reflect near-infrared radiation, so the rooms are heated less. Sharp says that this realignment, or 'phase transition', would ideally take place at 20°C-25°C.

Patent application number:
GB 2489670

The mouse that turns into a printer

THE DEVICES WE use while at work and play have shrunk in size dramatically in recent years, thanks to the rise of tablet computers and smartphones. But printers haven't kept up with the pace, as they've been limited by the size of the paper they use.

Jacqueline Stamp from Bedfordshire has come up with a clever solution to the problem and invented a printer that would fit into the palm of your hand. The

device consists of a small inkjet cartridge integrated into an otherwise standard optical mouse. Once set to print mode, the mouse is rubbed over the paper, printing the document as it goes.

Crucially, the computer remembers which pixels have been printed, so the image isn't duplicated when the mouse is moved over the same spot twice.

Patent application number:
GB 2490309



Holographic cards for TV poker

POKER ON TV is made possible by the 'hole cam', which lets viewers see a player's face-down cards. Now UK firm VX Enterprises has found a way to display adverts on cards that are visible to viewers but not to the players. Its modified cards have a holographic layer on their face which is visible from the hole cam's viewing angle, but not from that of the player.

Patent application number:
GB 2490353

ILLUSTRATOR: ROBIN BOYDEN, ACUTE GRAPHICS



THEY DID WHAT?!

Mediums have their own minds read

What? Brazilian mediums had their brains scanned during 'psychography' or 'automatic writing', whereby they enter a trance-like state and write, allegedly under the control of spirits. Ten mediums were injected with a tracer and then scanned using single-photon emission computed tomography (SPECT), during both normal writing and psychography.

What happened? The volunteers ranged in experience from 15-47 years. Those who are old hands at psychography showed lower levels of activity in several brain regions as it took place, including the frontal lobes – areas associated with reasoning and movement. But less expert psychographers showed increased activity in the same regions.

What does this show?

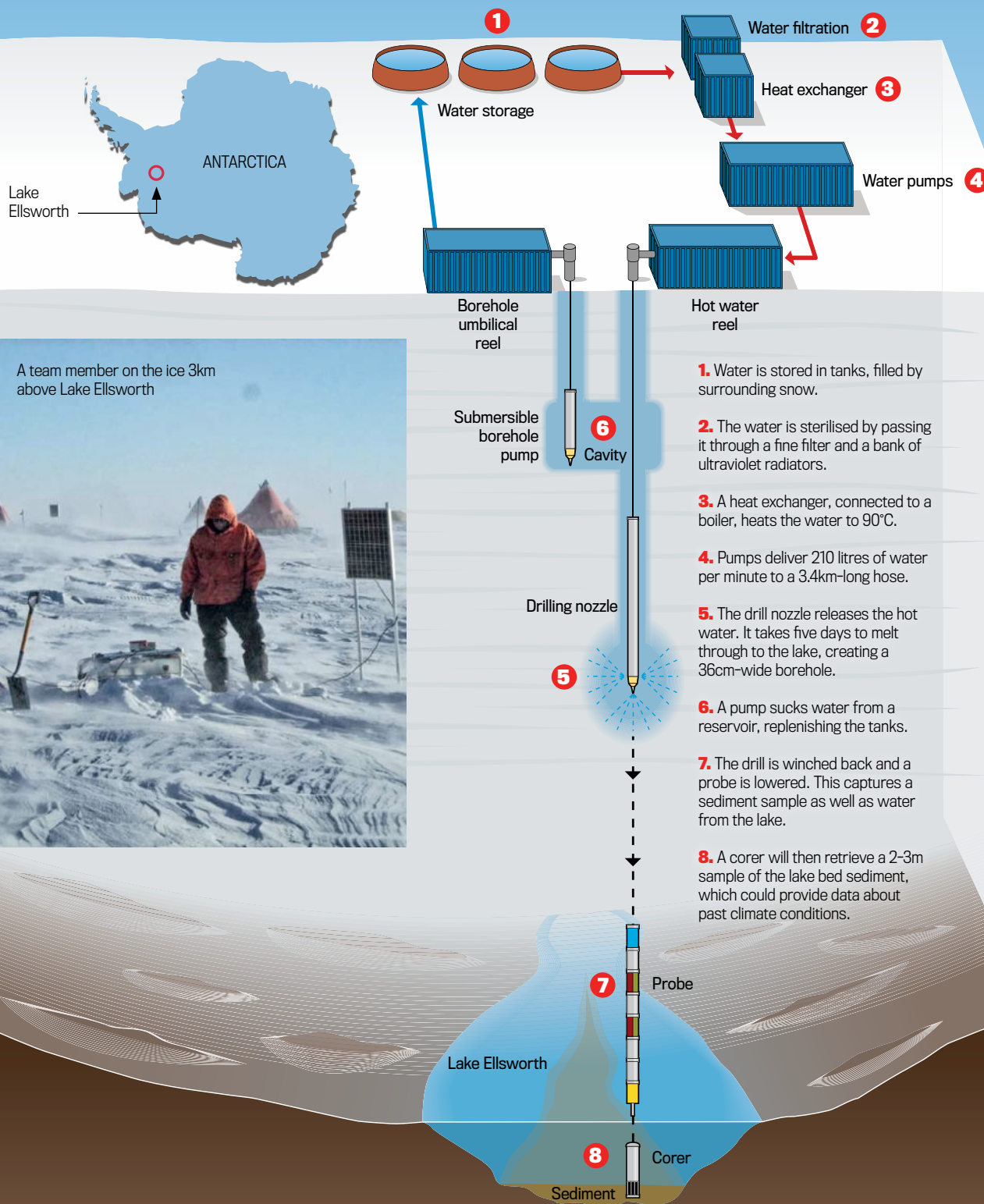
The neuroscientists say the increased brain activity may reflect more deliberate attempts among the less experienced to perform psychography. Lead researcher, Dr Andrew Newberg (pictured) of Thomas Jefferson University, says the findings require "further investigation both in terms of replication and explanatory hypotheses".

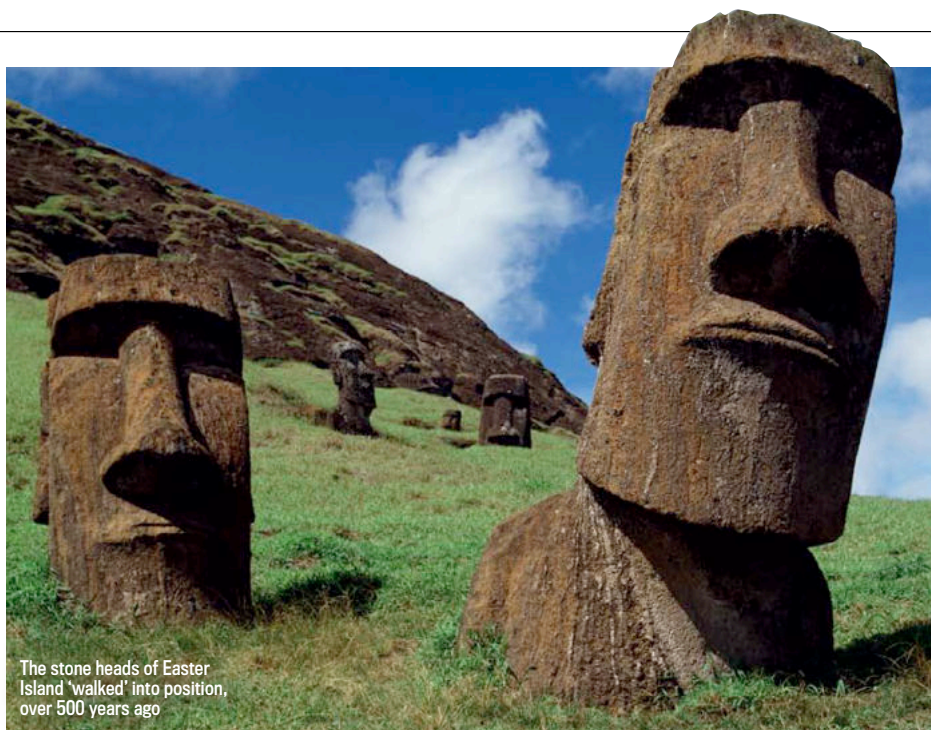


The hunt for Antarctica's lost world

THIS DECEMBER A team of British scientists is preparing to drill through 3km (1.9 miles) of ice to reach a lake beneath a glacier in Antarctica, to discover whether it is home to life. Hot water pumped at high pressure will be used to 'drill' a shaft to reach Lake Ellsworth, where samples will be collected. The existence or absence of life in the lake will be important for

astrobiologists. "Lake Ellsworth is a very good analogue for the ocean of Jupiter's moon Europa," says lead scientist Prof Martin Siegert, of the University of Bristol. "Both are protected by a layer of ice and have been isolated for long periods of time. If life survives in Lake Ellsworth, it's likely to be using the same biological processes as any life on Europa."





The stone heads of Easter Island 'walked' into position, over 500 years ago

Anthropology

Stone giants 'walked'

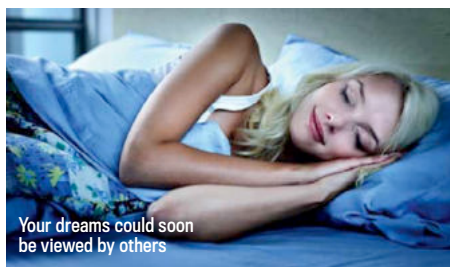
THE FAMOUS GIANT stone statues of Easter Island 'walked' out of the quarry where they were made, new research seems to show. Nearly 1,000 'moai' are dotted around the Pacific island, some weighing 74 tonnes. How the Polynesians, who arrived there 800 years ago, shifted the giants has been far from clear. Some archaeologists have suggested the settlers laid the moai flat before rolling them on logs. But now California State University anthropologist Dr Carl Lipo and colleagues say they have proved the statues 'walked' upright to their resting places by pulling a four-tonne replica along a hillside in Hawaii, rocking it back and forth with ropes. "It was amazing to see this unthinkably immovable object turn into a life-like thing," says Dr Lipo.

ZOE CORMIER

Neuroscience

New window into your dreams

NEUROSCIENTISTS HAVE FOUND a way to read your dreams – if you're lying in a huge brain scanner. In a Japanese study, researchers were able to determine whether someone's dream featured items such as a car or computer.



Your dreams could soon be viewed by others

But whereas in the film *Inception* the protagonists use a dream-reading machine to commit corporate espionage, the goal of this research is more benign. "It may help diagnose or treat sleep disorders," says Prof Yukiyasu Kamitani at the ATR Computational Neuroscience Laboratories in Kyoto, who led the study.

His team first asked three volunteers to fall asleep while they were lying in an fMRI scanner – a device that reveals areas of brain activity through high blood flow. They were then woken and asked what they had dreamed about. Over several sessions, researchers collected descriptions of over 200 dreams that included eating

a yogurt, using a computer or seeing a bronze statue. Finally, they showed the volunteers pictures of the items they had dreamed about, while scanning them again while awake. By comparing the sleeping and waking scans, the researchers were able to identify the sleeping brain patterns associated with specific objects. These patterns could then be used to read the dreams of others – as long as they dream of previously characterised objects.

The next stage is to try and decode what a person is doing in a dream. "We also plan to analyse different aspects of dreams such as action and emotion," says Prof Kamitani.

CHRIS SINCLAIR

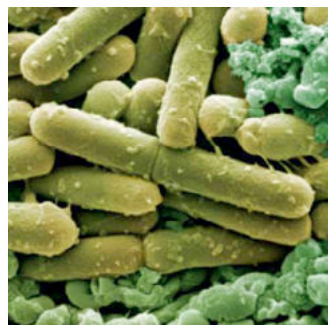
NEWS IN BRIEF

Anaesthetics make waves

• General anaesthetics work by disrupting communication between regions of the brain, but the exact mechanics is unknown. Now a team of neuroscientists at MIT have found that a loss of consciousness coincides with the onset of 'slow oscillations' in the cerebral cortex. These may lead to less efficient processing in some regions, disrupting communication.

End of faecal transplants

• A cocktail of six bacteria can fight off a *Clostridium difficile* infection. The bacterium lives in many people's guts, but an excess of it can be fatal. Some cases can be treated with a 'faecal transplant' in which material from a donor is mixed with water and passed down a tube into the stomach, but the six bacteria, taken as a pill, would be a more palatable remedy.



Clostridium difficile can be deadly if present in excessive quantities

Tourette's clue found

• A form of Tourette's syndrome has been induced in volunteers. Exciting the supplementary motor area (SMA) with transcranial magnetic stimulation (TMS) produced involuntary mimicking movements, like those involved in the tic echophenomena. The researchers now plan to see whether inhibiting the SMA with TMS can reduce genuine tics.



MASS

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What Hi-Fi? Sound and Vision. October 2012



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INSIDE SCIENCE

ROBERT MATTHEWS

WINTERY WEATHER, SOARING energy bills... these dank, dark days are enough to make anyone dream of living in one of those low-energy eco-homes, whose owners pad about in Bermuda shorts.

It sure beats wearing a hat, scarf and three sweaters to avoid being bankrupted by the next gas bill.

But here's a thing: according to new research, those eco-homes don't save energy, money or Mother Earth to anything like the extent people think. All of which raises big doubts about government campaigns aimed at persuading us to spend huge sums making our homes greener.

On the face of it, it makes sense to target homes in the drive to cut carbon. They're responsible for more than a quarter of Britain's energy use, and by European standards our homes are as green as a coal-fired Hummer. Yet attempts to do something about it through national drives to boost insulation levels have a reputation for failing to produce anything like the benefits expected.

In the search for explanations, suspicion has fallen on the computer programs used to estimate the savings achieved by adding energy-efficient measures. Perhaps they're based on faulty assumptions about how heat flows through homes. Or maybe they fail to take account of silly human habits like opening bathroom windows to clear steamed-up mirrors.

Evidence that pesky humans are indeed to blame is now emerging from studies of real-life homes. Using data from thousands of houses in the UK, Dr Scott Kelly at the University of Cambridge found that the much-vaunted energy ratings bore little relationship to actual energy use in a house. Much more important were factors like the number of occupants, their income and their pattern of energy use.

And that ties in with another suspicion about the differences in what computers think we do in homes, and what we actually get up to. It's linked to a phenomenon that's reared its head in other attempts to get people to mend their ways for their own good. Called 'compensation' or the 'rebound effect', it reflects the fact that humans have an annoying habit of changing their behaviour according to circumstances – and not always in a good way.

Classic examples are the introduction of anti-lock brakes and laws compelling the use of helmets by cyclists and skiers. Studies have shown that the expected safety benefits often fail to materialise because people compensate by taking more risks – such as driving

The real reason for insulating your home is so you can live in tropical climes, right?



“Humans have an annoying habit of changing their behaviour according to circumstances – and not always in a good way”

more closely to the car in front. Get fit campaigns suffer a similar fate: people go to the gym, burn off 200 calories and then reward themselves by scoffing a 250-calorie jam doughnut.

Dr Kelly's study has now found evidence for a similar rebound effect with energy consumption. It turns out that people in low-energy homes take advantage of the fact by turning up the thermostat – cancelling out the energy saving.

Now evidence has emerged for the flip-side. According to another team of researchers at Cambridge, people living in old, poorly insulated homes respond by saving energy whenever possible. Add these two effects together, and it's clear the computer models are doubly rubbish: they over-estimate savings achieved by low-energy homes and those achieved by improving old, cold ones.

Dr Minna Sunikka-Blank, one of the researchers involved in the latest study, points out that this raises serious doubts about the economic case for spending vast sums insulating homes. It simply won't bring the expected eco-bang for the taxpayers' bucks.

Of all the ways of doing one's bit for the planet, I thought insulating homes was a low-cost no-brainer. But if there's one thing I've learned about 'green' ideas, it's that they have a nasty habit of putting you in the red. ■

ROBERT MATTHEWS is Visiting Reader in Science at Aston University, Birmingham



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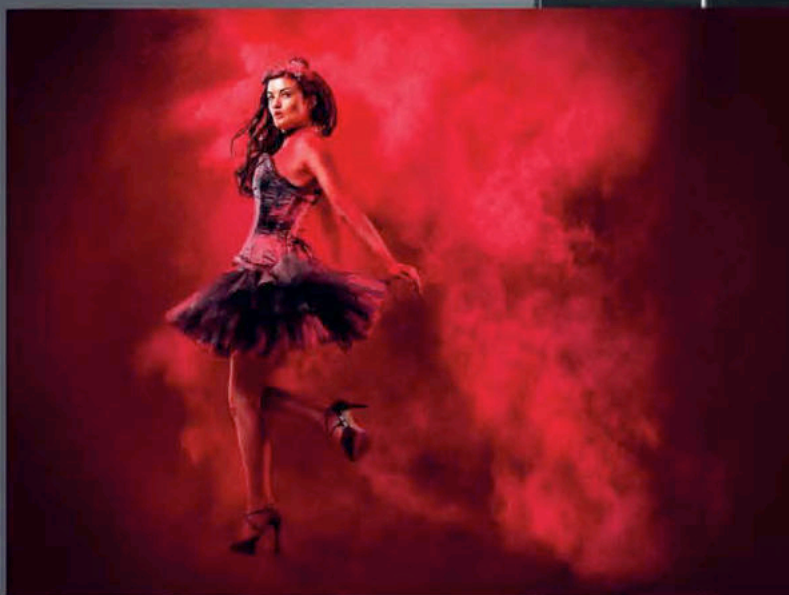
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FOCUS

BREAKTHROUGHS
OF

2013

From printing DNA to earthquake-cloaked buildings, science's biggest names predict the most influential discoveries of the coming 12 months

THE NEW YEAR means it's time to get excited about the scientific breakthroughs and technological surprises that will adorn the pages of *Focus* in the coming months. But what can we expect? We've asked the world's top scientists, including Jim Al-Khalili, Maggie Aderin-Pocock, Craig Venter and Stephen Wolfram, to give us their expert predictions. And if we've whetted your appetite, don't miss the new TV season *The Genius Of Invention*, which starts on BBC Two on 12 January. 

ILLUSTRATOR: STEVEN BONNER

BUILDINGS THAT HEAL THEMSELVES



MARK MIODOWNIK

Professor of Materials and Society at University College London and BBC presenter



WE'RE GETTING BETTER at manipulating materials at the nanoscale – creating tools from individual atoms and molecules. As a result, nanotechnology is being used in things like LED lighting, silicon and plasma technology. But we're going to see it applied to whole buildings.

There's a lot of interest in harvesting the energy from the Sun in big structures. If you can get every building to act as a solar collector, you've solved the global energy problem. There are already solar cell paints. At the University of Notre Dame, they have a solar paint that uses semiconducting nanoparticles to produce energy.

At Oxford, Cambridge and Cornell universities, they have developed semiconductors whose molecules self-organise into the optimal shape to collect light and transmit the resulting electrical charge. In their gyroid-structure solar cells, the semiconductors incorporate molecules that are hydrophilic and others that are hydrophobic – water-loving and water-hating respectively. These molecules want to pull apart, but the molecular links between them prevent this. So instead, they spontaneously form a 3D structure that is good for light collection and conversion to an electrical current.

The fact that the semiconductor forms the optimal structure spontaneously means it could be applied to large areas – including whole buildings. The big challenge now is

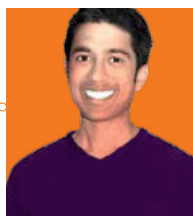
to figure out how you cover a building with loads of wires so you can use that absorbed energy. The answer isn't going to be people wiring up buildings with tiny wires. It's going to be conductive material that will self-organise into wires, a vein structure, and collect energy from the paint.

But the use of nanomaterials in architecture won't just be about energy capture. Buildings will also sense things and self-heal as part of what they are. After all, the reason we are so responsive – that we feel pain and heat – is that we have functional 'nanotechnology' in our cells. Evolution has optimised our cells to be able to detect things like heat and pain or if there's a crack in your skin. That's where architecture is heading.

“Buildings will sense things and self-heal. That's where architecture is heading”



GESTURE-CONTROLLED MOBILE PHONES



VIVEK GOYAL

Principal Research Scientist in the
Research Laboratory of Electronics at
Massachusetts Institute of Technology



I'M VERY EXCITED about the integration of 3D movement recognition systems into mobile devices. I think it's going to be a big thing in electronics that will take off soon.

Microsoft Kinect has transformed gaming because people are now used to using 3D gestural interfaces in computer games. Games are one use of these interfaces, but there's potential elsewhere too – including with mobile phones and tablets. Kinect is much larger than a phone and uses a lot of power, so a big challenge is scaling the system down for a mobile device. You want to make the sensors as efficient as possible and advances are being made. But there are also big gains to be made in how you process the data – and that's where my research group is involved.

Let's say your goal is to build a gestural interface, then what you are looking to gather is information about where the user's hands are. There will be other things in the field of view, such as walls.

But you are not looking to form a full image of the whole field of view. Once you reduce what you are interested in, then the mathematical modelling and processing allows you to get away with measuring less. We've built prototypes that demonstrate this.

People don't mind adopting new interfaces – a few years ago there were no touchscreens on phones. So consumers are willing to change. But one thing that isn't going to change is that you can't see through your fingers. On a phone, you're obscuring a significant proportion of your screen with them. So if you can do the same kinds of things with gestures as you do on a touchscreen – such as pinch to zoom – that's already a nice development. And once you can move your hands in three dimensions instead of two, then new ideas for different kinds of interface will come along.



Dr Henry Snait at Oxford University is at the forefront of efforts to make buildings harness power from the Sun

At the moment buildings are static: they are built and have to be repaired. If you're lucky they will automatically open and close a window. But in future, all the structures around us will be more responsive to the environment.

In this respect, we are working on a project where we're trying to make large objects touch-sensitive. So it's not just the screen of your mobile phone – it's your whole room.



+ STEM CELL ORGAN TRANSPLANTS

"I suspect that we will soon see one of the first liver or kidney transplants where the organ has been grown from the patient's own cells. So the organ is artificial – there is no donor.

We've already had trachea transplants with tracheas grown from a patient's own stem cells. But complicated organs are going to be harder.

The most significant breakthrough has been in the development of a scaffold material in which the cells can replicate and grow into a kidney, liver or eventually, perhaps, a heart. Once the organ has developed, the scaffold 'dissolves'.

This field of research really couldn't be any more exciting, because it solves so many problems."



You could soon be interacting with your mobile device without even touching it

+ INCREASINGLY POWERFUL ULTRASOUND

"There's a lot going on in ultrasound imaging research at the moment. Like in our 3D work and many forms of computational imaging, ultrasound is being revolutionised by improvements in data processing. It's also one of the medical imaging methods that tends to be extremely low cost. X-rays are not particularly cheap and can have long-term effects. And while MRI is non-ionising, and so doesn't damage cells, an MRI machine is a huge piece of extremely expensive equipment. Ultrasound can be cheap and what people can get out of ultrasound seems to be improving rapidly these days."

SUPER-EFFICIENT ARTIFICIAL PHOTOSYNTHESIS



ANDREA SELLA

Professor of Inorganic Chemistry at University College London



PHOTOSYNTHESIS IS INCREDIBLY inefficient. For most plants, the percentage of the incoming light energy which is actually transformed into sugar is around 1 per cent. So the challenge is on to beat those percentages – to make, say, hydrogen with 20 per cent efficiency. There's a lot of hype around hydrogen – it releases enormous amounts of energy when it reacts with oxygen, so it can be used in fuel cells to power anything from cars and buses, to ships and submarines.

There's been remarkable progress here, so significant developments are likely over the next 12 months. A couple of years ago, Daniel Nocera at MIT revealed the artificial leaf. This is a very clever device where a silicon photocell is coated so that, when dipped into water and exposed to sunlight, hydrogen comes off one side, and oxygen

the other. There was huge excitement when it was announced, but when they started looking at its scale-up costs and efficiency, the numbers just didn't add up. To solve this, people are now working on each of the three main steps involved in simulating photosynthesis. First, you've got to capture the light – this causes a negatively charged electron to be excited. Second, you have to separate positive and negative charges. Then, you have to harness these charges to do the water-splitting chemistry.

Our need for fuels far outstrips what sunlight can deliver through photosynthesis. So a system that's much more efficient would be a game-changer, because you could use sunlight and water to make meaningful amounts of fuel.



Daniel Nocera of Massachusetts Institute of Technology, holding his artificial leaf

+ BETTER HYDROGEN STORAGE

"Just imagine something that is a teaspoon in size and yet is so holey and porous on the inside that you'd need a football field's worth of wallpaper to cover it. These materials are known as 'metal-organic frameworks' (MOFs). In effect they're molecular sponges, and scientists are now targeting MOFs with cavities that are suited for particular molecules.

An MOF with holes that are of a very similar size and shape to the hydrogen molecule, and with the right sorts of intermolecular forces, can provide a way of storing hydrogen. Every week, there are people out there who are reporting MOFs with new structures and new shapes. It's hoped that someone will soon find one that's capable of storing fuel in the form of hydrogen gas with an energy density rivalling that of liquid hydrogen."

PHOTO: ORGANOV X3, LEN RUBENSTEIN

TRANSMITTING LIFE AT LIGHT SPEED



CRAIG VENTER

American biologist and entrepreneur who created the first synthetic species



WE'VE BEEN LOOKING at converting DNA into the 1s and 0s of computer code and sending that information

as a digital magnetic wave or an email around the Earth in less than a second. We're also building what we are calling a digital-biological converter that will take that digital information and convert it back into functioning biology.

"You'll be able to have a box next to your computer – the converter – and download insulin or a vaccine. With the H1N1 influenza virus, it took about nine months for the world to get a vaccine. In the US, 250,000 young people died in that interval. In the future, if there are lots of boxes around the world, it could be the end of pandemics. It's the start of being able to get biology over the internet.

The first part of the process is encoding DNA for a vaccine or insulin in digital form. So we read the sequence of ACTG [adenine, cytosine, thymine and guanine – the molecules whose sequence encodes the information in DNA] in the genetic material and convert that into the 1s and 0s on a computer. That information is then sent to the digital-biological converter. Inside the converter there are four bottles of chemicals and the genetic material is printed.

Using this DNA, we can make proteins. No cells are required – you can just make



This 3D printer developed by Organovo can take human cells and shape them into tissue

a dose of insulin from a biological reaction. Or, rather than producing a protein, we can simply convert the DNA sequence into an RNA vaccine and for DNA vaccines, all you have to do is synthesise the DNA.

The first practical use will be in sending vaccine information to large centres around the world that are equipped to make large doses of vaccine. The next step will be each government having its own ability to do that [print vaccines] and then eventually it will go to hospitals and corporations. A lot of regulatory hurdles will need to be overcome if people are going to do this in their own homes because it represents a fundamental change in how information is distributed and how information gets converted into meaningful things.

Anyone who has seen the movie *Contagion* would not want to see that played out around the globe. If we can prevent that, what a phenomenal contribution that would be.

I think standard manufacturing is moving towards distributed production using 3D printers. We are now making the first 3D biological printers. The first public tests and demonstrations of this will be done in 2013, so it's going to be an exciting year.

It will not just change how we deal with pandemics, but also how we think of biology and life.



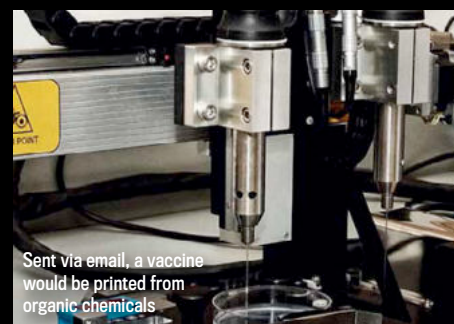
“We’re making the first 3D biological printers. The first public tests will be done in 2013 - it’s going to be an exciting year”

+ FURTHER DISCOVERIES ABOUT OUR PERSONAL ECOSYSTEM

“The microbiome [all the microbes that live on, and in, the human body] is going to become more and more important for human medicine. Over 2013, we will see a big scale-up in what can be done in terms of measuring the microbiome. There’s an increasing number of clear links between the microbiome and diseases. Our skin has a significant number of different environments: we have different microbes in different areas of our skin, such as the mouth and the vagina. All of these are being studied around the world. And, particularly with some gastrointestinal diseases, there are very strong correlations.”



Craig Venter is working on a similar device to Organovo's Bioprinter that can print vaccines



Sent via email, a vaccine would be printed from organic chemicals

CRACKING THE BRAIN'S CODE TO REPAIR DAMAGE



SHEILA NIRENBERG

Neuroscientist and principal investigator in the Nirenberg Lab at Cornell University in the US



OPTOGENETICS IS AN exciting area. There are light-sensitive proteins in algae, bacteria and fungi, the genes for which can be expressed in cells in the brain. When you shine a light on those cells, they produce an electrical signal. It allows you to make brain cells behave according to your control.

Others have been using this to drive neurones to fire, but the trouble is the brain uses its own code. It speaks a language like Morse code, but far more complicated. We figured out the code transmitted by the retina and we can make the optic nerve – the output neurones of the retina – send the normal coded signal to the brain. It's a treatment for complete blindness, where someone has a damaged retina with no photoreceptors. You can give them a device that sits in a pair of glasses and takes

images. It translates images into the brain's code as light pulses, so the optic nerve sends the right signal to the brain.

If you bring optogenetics together with the brain's code, remarkable things are possible. For instance, you could jump over dead sensory cells used in hearing or an area damaged by a stroke to make sure the brain receives the signal.

The code takes the form of equations. If you give someone a visual input and record the output of the neurones, you get equations that describe the relationship between input and output. Those equations are the codebook. If you put any visual stimulus through the equations, out comes the answer. It could work elsewhere in the body – determining the code of the auditory nerve, for example.

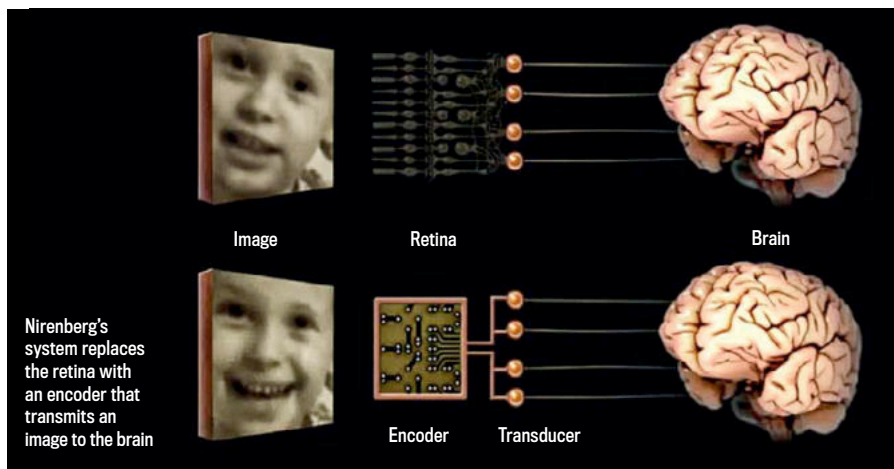


Jim Al-Khalili is working on an experiment looking at the effects of quantum mechanics on our cells

+ GRAPHENE-BASED NANOTECHNOLOGY

"A lot of funding is going into research on the properties of graphene, and especially into how it can be used in nanotechnology. Progress in nanotech was already speeding along, but the discovery of graphene has accelerated matters. This is because it's good at creating nanotubes, which are the building blocks of the nano-world. Certainly its properties suggest that it could soon enable the development of tiny 'robots' at the nanoscale. Graphene seems to be completely inert too, so it's perfectly suited for medical applications.

A lot of researchers working in this area are now submitting research grants involving graphene, because that's where masses of funding is coming from. Even chemists are getting in on the action because graphene appears to be almost impermeable to anything but water, so it could prove incredibly useful as a membrane for separating materials. This would enable us to get at the precious elements we're after."

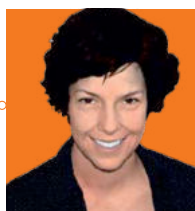


+ NEW AVENUES FOR ALZHEIMER'S RESEARCH

"There's potentially some exciting things happening with research into Alzheimer's disease at the moment. The conventional wisdom has been that what initiates the dementia happens to all brain areas at approximately the same time. Different areas of the brain may show Alzheimer's at different times, but they have all been targeted at the same time. In the same way that if you sneeze on a bunch of people, they may all get sick, but not at the same time.

However, there was a finding in April 2012 that when a person gets Alzheimer's they get dementia in one area, then another area, then another area. And there is a possibility that if it's a disease that spreads from one area to another, it could dramatically change how you treat it. If you can figure out a way to stop the spread, you can contain it."

BUILDINGS WITH MICROBIAL ECOSYSTEMS



JESSICA GREEN

TED fellow and Principal Investigator at the Green Lab, University of Oregon



THE MOST PROMISING innovation in the near future is 'bio-informed design'. Our homes, cars and phones all have these invisible ecosystems comprised of tiny life forms – bacteria, viruses and fungi – living on them. We spend 90 per cent of our lives indoors, so we should be asking how these unseen worlds are impacting on our health. We're able to do this now, thanks to advances in DNA sequencing. In particular, there's the Human Microbiome Project, which is identifying the microbial communities that live on and in the body. Our personal ecosystems really define our health, so the question is, 'can we influence the microbial ecosystems that we come into contact with for the better?'

Funding has been put forward by the Alfred P Sloan Foundation to discover exactly this – how certain architectural designs impact on microbial communities.

An obvious application will be in designing environments with a low chance of infection, like a hospital. We recently published a study that shows that natural ventilation alters the microscopic ecosystem indoors. So if you operate a hospital as normal – windows closed with air conditioning – you end up with a monoculture of microbes inside – a low variety of types. This monoculture will contain more microbes closely related to pathogens than if the building had been naturally aerated. We know that the more variety there is in an ecosystem, the less disease there is, and opening windows to let in outdoor air cultivates a rich variety of microorganisms inside. We still don't know that this will definitely reduce infection, and we're not there yet, but we will see this innovation in 2013.



Seen here as coloured patches on the sofas and walls, can we harness the plethora of microbes with which we coexist?

✚ SAMPLING THE BUGS THAT LIVE IN THE SKY

"There's a small cohort of aerobiologists who are now looking at charting microbial life in the atmosphere on a global scale, just like Craig Venter did with the oceans. We're talking about using rockets and high-altitude balloons. We're in talks with Red Bull to see if we can use their balloon system to sample life at 30.5km (100,000ft).

It's always been assumed that all of the processes going on in the atmosphere are just based on chemistry and physics. But there are some groups that think that if microbes are metabolically active in the atmosphere they could fundamentally change our understanding of atmospheric chemistry, global climate change and pollution."

PHOTO: MAGICTORCH, GETTY

NATURAL LANGUAGE PROGRAMMING



STEPHEN WOLFRAM

Creator of Wolfram Alpha and CEO of Wolfram Research



PEOPLE HAVE HAD the point of view up to now that there are programmers and then there are the rest of us. If you

want to get a computer to do something new that's not trivial, you need a programmer in the loop. But that's on the cusp of changing.

Software has been developing up to the point where, if put together in the right way, we will be able to introduce what's called natural language programming. It's one of these things that's been a gradual process for a great many years and I think we're finally at the point where we're at a qualitative change that's about to happen.

The idea is that rather than talk to your computer in computer language you can at least start in a language that you, as a human, know. It's something that you can see starting in Apple's voice-controlled Siri in a minor way. But what we're talking about is telling your phone, for example, that you want to take a picture with the second face on the left in focus. Or that you want all pictures taken before sunset in Bermuda put into one folder. We're at a point where the technology is powerful enough.

For example, part of this problem that's been solved is where the data sits. Until now, when you wrote a program, it would connect to a database that has the data you're trying to manipulate. But we can change that, so that the programming already has the data embedded in it, so there's no reason to



Wish you could tell your smartphone what to do with your pics? In the future you'll just be able to talk to it

run off and sift through all the information somewhere else. It already knows what left of your current position is, or when sunset was in the Bahamas. This will open up programming to everyone, especially kids. It'll be the first time children will be able to write non-trivial, powerful programs.

What we're effectively doing is automating a large part of the programming task, just as we've automated billions of other tasks. It's what we've done for the last quarter century. Today, you can write a piece of programming in five minutes that would have taken a month 25 years ago. Now a whole new level of automation in programming is about to break through to the consumer. And my theory is, the more you automate, the further humans can reach.



“Rather than talk to your computer in computer language you can at least start in a language that you, as a human, know”

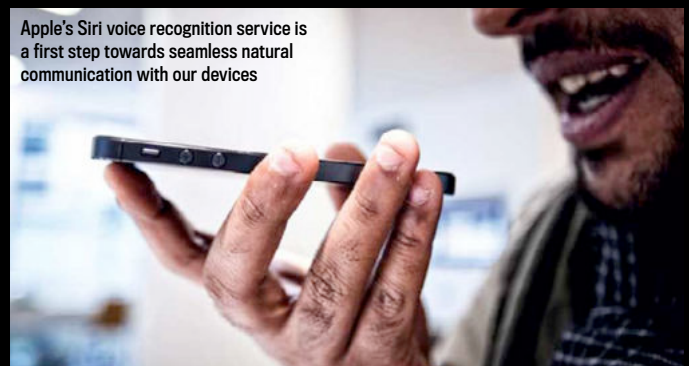
COMPUTERS THAT READ YOUR MIND

“You're using your computer, browsing the web or writing a program. The question is: given what you've done so far, can the computer predict what you're going to want to do next? The answer is, actually, yes.

Again, it's part of this automation story. Yes, you can have the human type the next thing they're going to do, but if the computer can figure out the five things that you're likely to do next and present them to you, it's an awful lot easier. We're in the position at Wolfram Alpha of having seen billions of actual query streams of people doing things with computers, so that really helps us make those kinds of predictions. We had to learn what those pesky humans actually do.”



Stephen Wolfram is working on a system for natural language programming



Apple's Siri voice recognition service is a first step towards seamless natural communication with our devices

SPOTTING POLLUTERS FROM SPACE



MAGGIE ADERIN-POCOCK

BBC presenter and research fellow at University College London



WE WANT TO monitor what people are doing and potentially give them penalties for adding pollution to the atmosphere. But policing that is quite hard work. The best way to do this kind of monitoring is from space and within the next year or so, satellites will be coming online that are capable of this.

There are two parts to pollution monitoring – measuring the pollution and measuring

the wind speed. When you combine this information, you have a better understanding of where the pollution is coming from.

Due to be launched in 2013, a European Space Agency (ESA) satellite called Aeolus will be able to measure wind speed. It uses LIDAR (Light Detection And Ranging), which sends a pulse of UV light into the atmosphere. Particles in the atmosphere reflect that light back, and because they are moving under the influence of the wind, there will be a small shift to the blue or red parts of the electromagnetic spectrum depending on whether they are moving towards or away from you. If you can work out how particles are moving you will know the wind speed.

A number of teams are also working on detecting carbon dioxide (CO₂) levels from space, so we're likely to see developments here soon too. Some of this research has been done at Imperial College London and they tested a system from an aircraft that works. But getting CO₂ detection to work in space is quite a big job.

People producing the greatest emissions should pay the most, but at first it will be done on an industrial level – I don't think anyone will be monitoring our homes just yet.



ESA's Aeolus satellite undergoes testing – it's set for launch in 2013

+ BIG IDEAS ABOUT SMALL SATELLITES

"Some of the satellites I've worked on have been the size of a bus, but the idea of small satellites is exciting. We've already got CubeSat – a 10x10x10cm cube that you can put simple devices into. There's been talk of putting something that looks like a solar sail onto a CubeSat to collect space debris. Or you could have a crowd of small satellites that are little more than printed circuit boards flying equal distances apart. If they had cameras you could get a stereoscopic view because you would have multiple viewpoints. So that would be one use that would be very powerful."

BUILDINGS CLOAKED FROM EARTHQUAKES



WILLIAM PARNELL

Director of Applied Mathematics at the University of Manchester



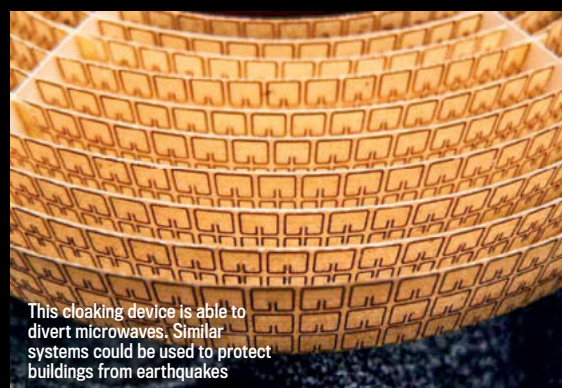
IN THE LAST year or so, materials science has really started to crack cloaking. Through mathematical modelling we've started to create metamaterials. The idea is that we take a material and change its microstructure at certain points, with the result that it guides waves around what we're trying to protect. And it does this without changing any other crucial properties.

So in an extreme example we could create foundations that channel waves from an earthquake away from the building, without compromising its strength. More realistically, you could perhaps do this around critical points of the building. The difficulty is in changing the density of a material in a reliable way without altering its other properties. That's where the tricky mathematical modelling comes in.

Simultaneously, there's another approach being developed that involves what are called phononic and photonic materials. The idea here is that rather than channelling the waves in a certain direction, the structure of a phononic material stops sound waves in their tracks, while photonic material absorbs light.

For example, you could have a filter that stops elastic waves, so you could protect machinery from certain vibrations that could be damaging. The challenge here is to create a material that has a microstructure that matches the wavelength of whatever it is that you're trying to stop.

Work in both of these fields has rapidly accelerated over the past couple of years. This is a result of the discovery of graphene and the many new possibilities it opens up to scientists – especially now that the Institute of Graphene Research is opening up in Manchester this year.



This cloaking device is able to divert microwaves. Similar systems could be used to protect buildings from earthquakes

+ MORE RAPID INJURY REPAIR

"We could see a breakthrough in modelling biological materials. The goal is to accurately model soft tissues like cruciate ligaments – which footballers often injure – so we can repair them with materials that best mimic the body's. Our mathematical models for recreating this kind of tissue are getting closer to the microstructures we see in the body." ■

BBC TWO

The first episode of *The Genius Of Invention* airs on BBC Two on 12 January.

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At the heart of the image



The Christmas Lectures are back with a bang, with an explosive series on chemical elements. Presenter Peter Wothers tells **Daniel Bennett** about burning holes in his bedroom...

ELEMENTS

YOU MIGHT MISTAKE Dr Peter Wothers for a chef if it wasn't for his trademark yellow lab coat and goggles. A sprinkling of strontium and a dash of lithium is the kind of measurement you'd expect from Jamie Oliver preparing a salad, not a chemist conjuring metre-high flames. But this casual confidence is the result of a practised hand. As a Teaching Fellow at the University of Cambridge, Peter has spent a lot of time playing with fire in front of students. We caught up with Wothers at the august surroundings of The Royal Institution, as he prepared to deliver this year's series, titled *The Modern Alchemist*, on BBC Four.

You're following in some big footsteps - Michael Faraday for one. Does that make you a little nervous?

There are no nerves at the moment. I mean, it's a great honour, but I haven't got time to worry about nerves. If you stop and think who's given these lectures so far, it's pretty daunting. Unfortunately I just don't compare to Faraday. The man revolutionised humanity. That said, he did start these lectures to get 'young folk' interested in science, to educate them, and I certainly hope that's what I'll be doing.

What will you be covering?

I thought it might be nice to go back to the ancient Greek elements Water, Air, Earth and Fire. Of course there are four of them and only three lectures, which is a little inconvenient. So I decided, since fire is an imponderable thing, that we'd run with Air, Earth and Water. Besides, there's plenty of fire in each show.

First, we look at the elements you find in air, where you come across individual atoms that aren't bound to anything. It makes air a great place to explain the difference between elements as they act within compounds, and how they behave

on their own. Second, we'll look at the elements in water. Of course, water is only made of two elements - hydrogen and oxygen - so one of the focuses will be on the energy released when these two elements combine.

Finally, we'll look at the elements in Earth. We'll examine how man has harnessed them, starting with copper and iron, right up to the more modern exotic materials that we've gradually been able to isolate and use. These include silicon and, more recently, the rare earth magnets that are increasingly used in technology today.

What drew you to chemistry?

I remember hearing my great aunt Gladys talking to my mum about chemistry sets and how you could change the colour of a piece of paper from pink to blue. It sounds simple now, but as a child it seemed incredible. And of course they were talking about something as simple as → the classic litmus test.

Ghosts of Christmas past: notable lecture series of years gone by

1825 John Millington

The idea to hold Christmas Lectures came from Michael Faraday, but he didn't present the first series. That honour belonged to John Millington, Professor of Mechanics at the Royal Institution. The subject was 'natural philosophy', better known today as science.

1848 Michael Faraday

A hugely popular speaker, Faraday presented 19 series. A transcript of his 1848 lectures, *The Chemical History Of A Candle*, became one of the most successful popular science books of all time.



1881 Robert Stawell Ball

A professional astronomer and author, Stawell Ball presented 'The Sun, The Moon And The Planets' in 1881 - the first of his five Christmas Lectures. Ball's skill as a lecturer made him a wealthy man, earning him fees from talks all over Britain, Ireland and the USA.

OF SURPRISE



1966 Eric R Laithwaite

Laithwaite's series, 'The Engineer In Wonderland', was the first to be broadcast on TV. Shown on BBC Two for over 30 years, the series has been on BBC Four since 2010.



1973 David Attenborough

Attenborough was controller of BBC Two when the Lectures were first televised. In 1973 he'd returned to broadcasting. He said the hardest part of his lecture, 'The Language Of Animals', was the live studio demonstrations.

1977 Carl Sagan

Sagan's 'The Planets' covered Solar System exploration and discoveries made by the Viking missions to Mars. He became best known for his US TV series *Cosmos*.



1991 Richard Dawkins

Famous for his book *The Selfish Gene*, Dawkins tackled evolution in his enthralling series 'Growing Up In The Universe'. He could also boast a celebrity guest - author Douglas Adams made a brief appearance standing on a pair of scales.

1994 Susan Greenfield

After 169 years, neuroscientist Greenfield was the first woman to present the lectures. Nancy Rothwell, Monica Grady and Sue Hartley followed later.





Dr Peter Wothers cooks up a chemical storm in preparation for the Christmas Lectures

➔ I was fixated on chemistry from about the age of eight. I recall burning a hole in the Ottoman in my bedroom with my first chemistry set. That got me banned from the bedroom so I had to move my lab to an outhouse. It grew bigger and bigger. Then in my teens, I got a job working for laboratory suppliers and they paid me in chemicals and apparatus. So as a young student I had centrifuges, Bunsen burners, condensers and so on.

It gave me an understanding of the world around us, how we interact with it, and what things are made of. That's why these lectures are so important – to engage young people. I look at the seats we're sitting on and I can think about the materials and what they're actually made from – the different elements, how they're put together and so on. It's that level of understanding that got me really excited.

What keeps you interested in chemistry today?

I think it's just amazing that new materials are still being discovered, even simple ones with just one or two elements. You'd think we'd know everything there is to know about the elements, but of course relatively recently there's been two Nobel Prizes, just for different forms of carbon. There's the buckyballs [fullerene] discovered by

"I recall burning a hole in the Ottoman in my bedroom with my first chemistry set"

Harry Kroto and then more recently graphene with its wonderful properties. But that's just one element. When you start putting elements together there are so many different possible combinations. Who knows what we're going to find in the next few years?

Do you have a favourite reaction?

It's probably the preparation of nitrocellulose or guncotton. It looks like cotton wool, but then all of a sudden with a bit of warmth, it completely disappears. It's something I did when I was a child, when you could get proper chemistry sets. I used to go to our local chemists and buy all sorts of things. Eventually, I got hold of some concentrated acids [that you need to prepare guncotton]. There were so many things involved that would be forbidden today!

How do you make it?

Carefully.

If your audience learns one thing, what do you hope it will be?

What the world is made up of. On one level, it's the tiny things that can be made by smashing other tiny things together in a particle accelerator, but on a practical level the world is made up of the elements. Take the story from the newspapers recently about how researchers had made petrol from air. That story is about the conservation of matter. The point is that if you burn petrol, you're forming CO_2 . You could collect those molecules, rearrange the carbon atoms and put them back together as a molecule of petrol. Because of the conservation of matter you never destroy the atoms – you're simply rearranging them. And that's the challenge of the chemist: to come up with arrangements that have new properties. ■

Find out more

BBC FOUR The Royal Institution Christmas Lectures will be broadcast on BBC Four in late December.

Watch classic Royal Institution Christmas Lectures at:
<http://richannel.org/christmas-lectures>



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THE EQUATION THAT COULD SAVE THE WORLD

From financial crises to freak floods, a (fairly) simple mathematical formula has the power to tame a whole host of calamities, says **Robert Matthews**

SOME SAY THE first hints of the disaster emerged one summer morning in 2007, with an announcement from a leading French bank. Others insist its origins lay years, even decades earlier. What no-one doubts is that the consequences were world-wide, devastating and very nearly apocalyptic. Commentators called it a 'credit crunch', but it soon became clear this utterly failed to reflect its magnitude. Among experts it is now referred to via a codename, as if they can barely bring themselves to talk about it. They call it the GFC – the Global Financial Crisis. We're still living with the consequences, but there is hope for the future. A single mathematical formula may have the power to prevent such a catastrophe in the future.

On that August day in Paris, BNP Paribas warned it was suspending billion-euro funds whose true value was no longer certain. This signalled the start of a series of calamities that engulfed the world's financial institutions. A sprawling network of global transactions – gambles, according to some – had unravelled in unexpected ways, supposedly small risks of default having proved to be anything but.

PHOTO: GETTY

Unable to cope with the resulting tsunami of demands for payment, huge financial institutions had to be bailed out by governments with astronomical sums. Even now, the total global bill for the GFC continues to grow, and looks certain to top £10,000 billion.

Attention has focused on ensuring it never happens again. And this month sees the launch of the centrepiece of attempts to prevent another GFC. Known as Basel III – after the Swiss-based banking organisation behind it – it's an internationally agreed set of rules aimed at stopping banks needing bailouts. It requires banks to possess enough money

"Its elegance allows one to build up sophisticated risk formulae and trading strategies"

Dr David Orrell, mathematician and author of *Economyths*

to get them through any future crisis triggered by bad bets.

Yet even before they come into force, the rules have been attacked as unfit for purpose. Many experts believe Basel III is too complex, all but guaranteeing that greedy banks will find loopholes allowing them to go back to their bad old ways while dodging the consequences.

But most concern focuses on how Basel III deals with the root cause of the GFC disaster: risk.

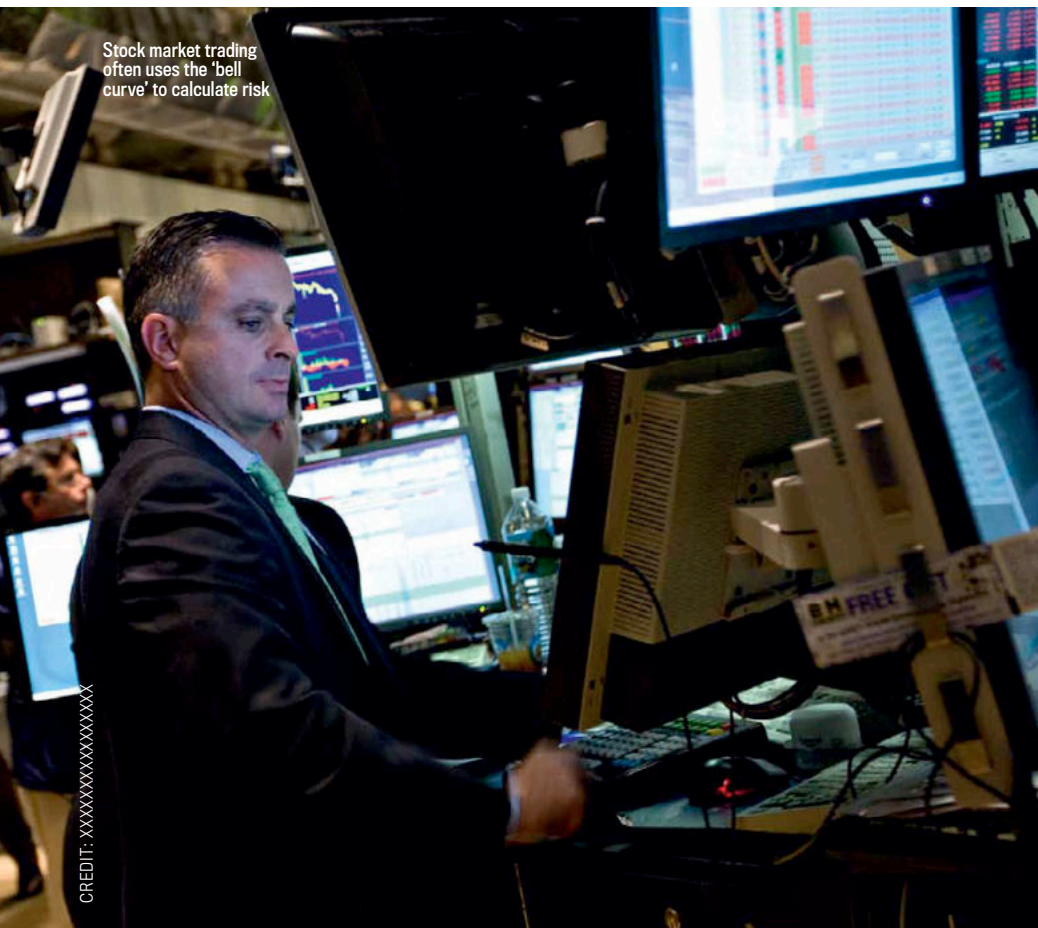
Risky business

Banks and other financial institutions constructed multi-billion dollar businesses on the back of hopelessly flawed estimates of the likely risks of, for example, homeowners defaulting on their mortgages or businesses going bankrupt before they paid off their debts. Ratings agencies came up with figures that proved tens or even hundreds of times too optimistic.

"In the run-up to the crisis, the financial sector refused to learn," says Professor Paul Embrechts, a leading expert on risk calculation at the university ETH Zurich. "As the music was playing, everyone was dancing." When the music stopped, those caught out seemed genuinely stunned that their calculations could have proved so wrong. Just days after the BNP Paribas announcement, a senior manager at leading US investment bank Goldman Sachs told a reporter that its funds had been hit by risks that the company estimated should never have occurred in the lifetime of the Universe.

Yet experts like Prof Embrechts say the cause of the GFC wasn't appalling bad luck, but hopelessly inadequate ways of calculating risks. They believe a radical overhaul is needed, one centred on a method that's proving its worth in assessing extraordinary threats, from extreme weather events to the flooding of entire nations. It's called Extreme Value Theory. At its core lies a simple but profound truth: extremes can really catch you out.

It's a maxim with particular resonance for those charged with calculating the risk of anything from losing a bet to going bankrupt. That's because for centuries they have based their calculations on something called the 'normal curve'. This shows the chances of random events leading to outcomes different from the average. Nicknamed the 'bell curve' (see graph opposite), it reflects the commonsense idea that unusual events get progressively less likely the more outlandish they are. Its predictions have also been confirmed countless times, from surveys of children's heights



Stock market trading often uses the 'bell curve' to calculate risk

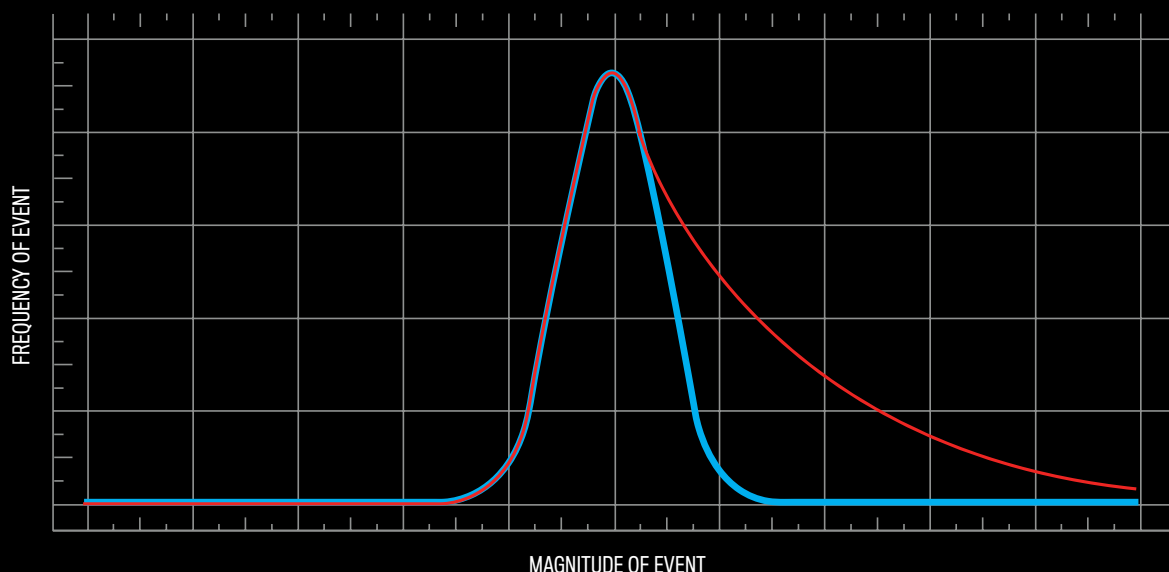
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INSIDE THE EQUATION

The inner workings of the formula that predicts extreme events

BELL AND EXTREME VALUE CURVES

Some events follow the 'normal' distribution, while others don't...



● IQ scores of schoolchildren, people's heights and even the length of bananas follow the so-called 'bell curve'. It shows how values are spread about the average, due to random effects combining together.

Bell curves are described by two numbers: the average and the standard deviation. The first gives the value at which the bell curve peaks and the second reflects the spread of the values either side.

● Extreme events like stock market crashes don't follow bell curves. Because they're extreme, and therefore unusual, they follow their own special curve which isn't symmetrical.

BREAKING DOWN THE EXTREME EQUATION

The key components of the formula

The Generalised Extreme Value equation gives the chances of any given value of, say, flood height - given by X - being beaten over a specified timescale, such as a decade.

The value of μ (μ), known as the location parameter, gives the minimum value of X at which record-breaking levels start. It fixes the starting point of each extreme value curve.

The value of σ (σ), the 'scale parameter', describes how spread out the values of X are over time. σ therefore reflects the variability of historical record levels.

The shape parameter, ξ (ξ), shows how distorted the extreme value curve is compared to the bell curve. The more extreme the value of ξ , the less symmetric the curve will be.

Once these numbers have been input, the extreme value curve they generate gives estimates of the chances of future events exceeding a record.

$$f = \frac{1}{\sigma} \left[1 + \xi \left(\frac{x - \mu}{\sigma} \right) \right]^{(-1/\xi) - 1} \exp \left\{ - \left[1 + \xi \left(\frac{x - \mu}{\sigma} \right) \right]^{-1/\xi} \right\}$$

PREDICTING THE FUTURE

The equation can be used to make startling forecasts

9.36

seconds is the potential record time for the men's 100m, which currently stands at 9.58s. Researchers at Tilburg University in the Netherlands applied the equation to over 1,000 athletes' times to predict it.

124

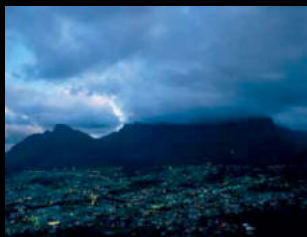
is the estimated maximum human lifespan, published by extreme value experts at Erasmus University, Rotterdam. The record holder, Jeanne Calment, died in 1997 aged 122.

2024

is the year after which the next record-breaking stock market crash could happen, as predicted by economists Prof Manfred Gilli and Dr Evis Kellezi of the University of Geneva.

From weather prediction to having a big win at the races, the Generalised Extreme Value formula has a wide range of uses

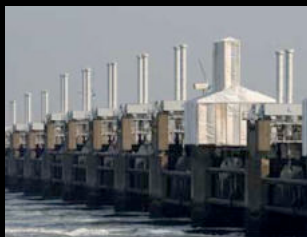
HOW EXTREME VALUE THEORY...



...MAKES SENSE OF EXTREME WEATHER

On 1 August 2006, the city of George (pictured) in South Africa experienced the worst downpour ever recorded in the region, with an astonishing 230mm of rain falling in one day – double the previous record. To gauge the significance of this extreme weather event, a team at the University of Cape

Town turned to EVT to estimate the 'return period' for such a downpour. By analysing over 60 years of daily rainfall records, the team discovered that such an event was unlikely to happen again for over 1,200 years. So despite the headlines, the event did not justify huge sums being spent preparing for a repetition. Extra preparations were made, but they were moderated by the equation's predictions. EVT also showed the region had been lucky: there should have been at least one repetition of the previous record set in the 1960s, which had a return period of just 23 years.



...HELPS PROTECT THE NETHERLANDS

With 20 per cent of its land – and population – living below sea-level, the threat of devastating floods has loomed over the Netherlands for centuries. And sometimes it has materialised, as in February 1953, when a deadly combination of high tides plus winds led to a storm surge that breached the sea

defences, leaving 1,800 dead and tens of thousands homeless.

Following the disaster, an expert panel set about designing sea defences that would prevent a repeat for many centuries. Analysing data on past record-breaking floods, EVT expert Professor Laurens de Haan and colleagues at Erasmus University in Rotterdam, calculated that sea walls (pictured) over 1m higher than the 3.85m level reached in 1953 would be needed. And today, over 60 years later, EVT continues to protect the 3 million Dutch people living below sea level.



...MAINTAIN A TIPSTER'S REPUTATION

Many amateur gamblers rely on tipsters to recommend horses worth backing. And few tipsters have a record to match Tom Segal (pictured centre) of *The Racing Post*. Using the pen-name PriceWise, Segal has a reputation for recommending unfancied horses who win more often than their

odds suggest, thus generating a profit. But while the wins are big, they're also pretty infrequent, with long losing streaks. In 2011, Segal hit a streak of 26 consecutive bad tips – prompting many of his followers to worry that he'd lost his touch. Yet EVT shows that such a run of losers is entirely expected during the 200-plus tips Segal produces over a year. Sure enough, the bad run ended in the summer, and Segal went on to produce an impressive 20 per cent return on investment for those who kept the faith.

to the outcome of casino games. Yet the pervasiveness of the bell curve has fooled many into believing it is also omnipotent. For decades, mathematicians have been warning that, like all rules, it has its limitations. As its name suggests, it breaks down most badly in situations that are anything but 'normal'. And that has huge implications for those trying to fathom the risk of extreme events.

The first clues to just how huge these implications are emerged during the 1920s, when mathematicians in France and the UK pointed out that extreme events follow their own special distributions, quite distinct from the normal curve. The mathematicians proved there were three basic types, which were later combined in one single formula: the Generalised Extreme Value (GEV) equation (see 'Inside the all-powerful equation', on p51).

Given its more demanding uses, the GEV formula is more complex than that governing the bell curve. The biggest difference lies in the 'tail' seen in its curve. This long, sweeping part of the line shows the chances of seeing ever-more extreme events. With the bell curve, this tail gets thinner pretty rapidly, implying that the risk of unusual events falls away quickly. Not so with the GEV curve, however, which typically has a thicker, 'heavier' tail.

GEV it a go

The lesson is clear: anyone who uses a bell curve to estimate risks of extreme events is likely to reach hopelessly optimistic conclusions – with potentially disastrous consequences. According to Embrechts, the GEV curve is a key part of the toolkit needed to deal with real world risks. "It points out the limitations of the bell curve and yields scientific tools to describe and understand low probability events," he says.

As such, Extreme Value Theory would seem to be crucial to ensuring financial institutions never again take on risks they can't handle. Calls for its use have been circulating for some time, with Alan Greenspan, former chairman of the US Federal Reserve, arguing for wider adoption of it following a bout of market turmoil in the mid-1990s.

So why didn't financial institutions do more to protect themselves before the GFC struck? Cynics argue that the banks weren't interested because when their risky gambles paid off, they kept the profit, but knew they were too big to be allowed to fail if the gambles went sour.

Some believe, however, that the brilliant maths and physics PhDs employed by banks to handle risk had fallen under the spell of the beautiful and ubiquitous bell



“In the run-up to the crisis, the financial sector refused to learn”

Professor Paul Embrechts, a leading expert on risk calculation at the university ETH Zurich

curve. “Its elegance allows one to build up sophisticated risk formulae and trading strategies,” says the mathematician and author of *Economyths* Dr David Orrell. “But studies have shown that financial data is not best fit by the normal distribution. In particular, it assigns effectively zero likelihood to extreme events”. And that casts a huge shadow over Basel III and its approach of preventing another GFC, because it permits financial institutions to continue using old, bell curve risk calculations.

According to Dr Ming-Shann Tsai of the National Chi Nan University, Taiwan, this raises the spectre of banks once again underestimating the risks

of their gambles going wrong, and thus failing to have enough capital to cover the consequences. Working with Dr Lien-Chuan Chen of Taiwan’s National Central University, Dr Tsai has compared the capital reserves required by Basel III with those demanded by Extreme Value Theory. The results are sobering: the Basel formulae underestimate the amount of money a bank needs by as much as 250 per cent. Relying on the bell curve, the pair conclude, “is likely to inaccurately estimate the bank’s exposure”.

Fears about the adequacy of the new rules may prompt a re-think by the Basel committee. But whether it will demand the use of Extreme Value Theory remains to be seen. However, not everyone is convinced by the way Extreme Value Theory uses past records of extreme events to estimate future risks. “Risk assessments which are based purely on calibrating probabilities using past data are likely to fail at crucial times – no matter how sophisticated they are,” says Dr Paul Ormerod of the economics consultancy Volterra Partners. He argues that the increasingly interlinked nature of finance plus fickle human behaviour

can make a mockery of predictions based on the past. The events of 2007 are an example. “One minute, banks were happy to lend to each other – the next, sentiment suddenly altered and the inter-bank loan market froze,” he says. “Nothing dramatic had happened to precipitate this.”

No-one is saying Extreme Value Theory is a panacea for the age-old problem of judging risk. But there is now a wealth of evidence that it’s far better than the bell curve methods used. And if regulators don’t force a re-think, the risk is that we will end up footing the bill – again. ■

ROBERT MATTHEWS is a Visiting Reader in Science at Aston University, Birmingham

Find out more



Watch an episode of programme *Business Daily* looking at the doubts about Basel III: <http://bbc.in/SSI6gm>

Video explaining Extreme Value Theory: <http://bit.ly/TuhayF>

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CREATURES GREAT AND SMALL



The first global census of the oceans' smallest inhabitants – the plankton – is revealing how important their world is to ours, finds **Chris Bowler**

GHOSTLY ASSASSIN

The transparent crustacean *Phronima* is found throughout the world's oceans, except polar regions. Measuring only a few centimetres, it uses its impressive claws to hollow out its victims such as salps and pyrosomes.

THEY GENERATE HALF the oxygen we breathe and their remains are responsible for all our petroleum reserves, as well as huge geological structures like the white cliffs of Dover. They also lie at the very base of the marine food chain. As such, every animal in the world's oceans relies on their existence. And now, for the first time, a global census has been carried out revealing the true diversity of plankton – the tiny organisms that drift with the currents.

For over two years, a small research schooner called Tara – owned by



➡ the French fashion house Agnès B. – traversed the world's oceans taking samples of seawater laden with plankton. Preliminary data from the Tara Oceans project has revealed just how diverse this group of organisms is.

As Tara toured the world, the international research team on board collected water samples from 150 carefully selected sites from the tropics to Antarctica. These are providing insights into the kinds of plankton found in different environments, including those hit by pollution, those prone to ocean acidification and those around melting ice. In all, the 65,000-nautical-mile (120,400km) expedition collected close to 30,000 samples.

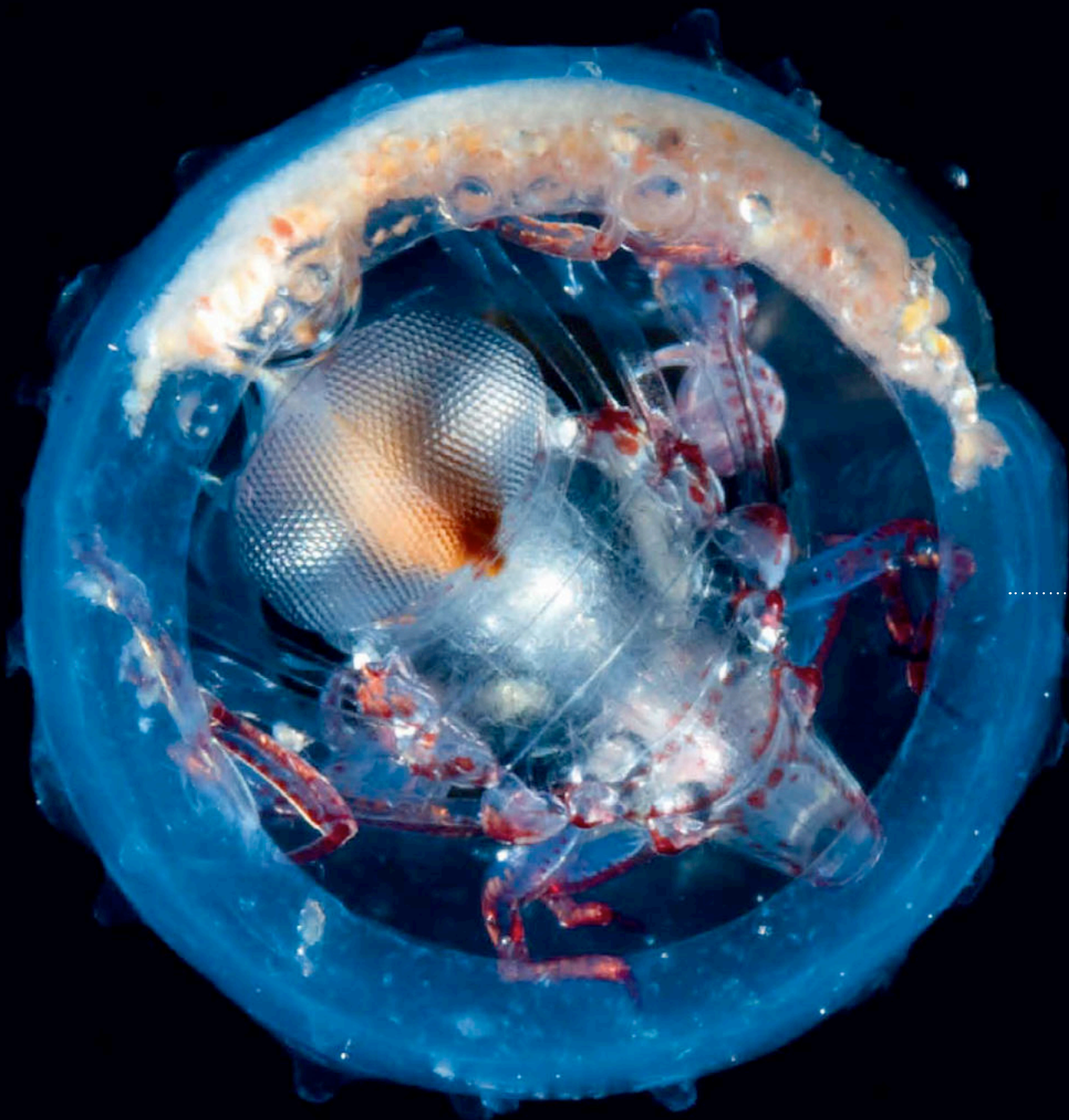
The samples are now being analysed by a consortium of scientists including oceanographers, experts in genomics and cellular imaging, as well as statisticians based in laboratories as far afield as Europe, the US, and Japan. Their overall objective is to identify as many organisms as possible. It's a task that the latest in rapid DNA sequencing is facilitating. As well as allowing identification, studying the collection of genes found in each organism is providing insights into their lifestyle.

Preliminary unpublished data suggests that there's more than a million species of eukaryote plankton – plankton with nuclei. Only about 10 per cent of the species found in the study were previously known. The diversity of the nucleus-

free prokaryotes – the bacteria and 'archaea' – appears to be much lower.

Although microscopic, plankton make up 98 per cent of the weight of all organisms in the oceans, the other two per cent are fish and mammals. They are affected rapidly by changes in climate and in turn, they affect the climate by modifying the absorption of carbon. So there's a real urgency to understand how the plankton ecosystem – the only one that almost covers the entire globe – will evolve. ■

DR CHRIS BOWLER is a biologist at École Normale Supérieure in Paris and an expert in genetics for the Tara Oceans team



ALIEN INVASION

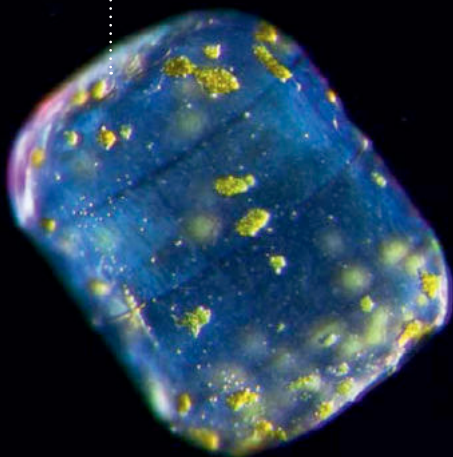
The amazing Phronima could easily have been an inspiration for the Xenomorphs seen in the *Alien* films. These deep-sea crustaceans have two pairs of compound eyes. Two of the eyes form a helmet-like structure – a classic adaptation to deep sea life, allowing a creature to collect the tiny amounts of light that reach the depths. When a female Phronima has invaded a victim – as it has here – it makes a barrel-shaped house out of its prey's gelatinous shell. The females deposit their eggs into the new home that drifts across the oceans.

**SIMPLE SIPHONS**

There's no need for a microscope to catch a glimpse of a salp. They resemble small sacks of gelatine and are between 1 and 10cm long. They belong to the tunicate family, ancient ancestors of all vertebrates, including us. They move about by pumping water into their tubular body and tensing muscles to push it out.

LUNGS OF THE WORLD

Diatoms have protective cell walls made of glass – they are built out of silicon dioxide, the same molecule found in windows. The gold flecks inside the cell are chloroplasts, where photosynthesis takes place, and they typically live in the sunlit upper layer of the oceans. Diatom photosynthesis is responsible for about one-fifth of the oxygen we breathe, as much as all the rainforests combined. This giant diatom is 2mm in size and was collected in the Indian Ocean.

**WIDESPREAD WONDER**

Copepods are abundant zooplankton – the animal plankton – that feed on unicellular algae and protists. In turn, they form the staple diet of many fish. There are thought to be 10,000 species of these small crustaceans.

IN THE PINK

Coral is an animal that lives in symbiosis with algae, a form of plankton. In exchange for shelter, the algae provide it with oxygen through photosynthesis. They are also responsible for their colour. This unusual pink coral was found off Saint Brandon, an island in the Indian Ocean.

**MARINE ANACHRONISM**

Platynereis is a segmented worm that lives in many marine environments and can grow up to 6cm long. It is considered a living fossil because it has many ancestral features. One of the most interesting is an eye-like structure called an eyespot that resembles the first eyes that developed. The eyespots allow its plankton larval form to navigate, guided by light.

THE SCIENCE SHIP

A total of 126 scientists took turns on Tara on its three-year global voyage. The 150 sites were typically sampled at three depths down to 1,000m.



PHOTO: M.ORMESTAD X3, C.SARDET X2A AMIEL, ERIC ROETTINGER

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HOW TO PHOTOGRAPH A BLACK HOLE

Astronomers are closing in on their most elusive target. **Heather Couper** looks at how a new telescope will reveal these extreme objects

WHAT DO YOU need to get up close and personal with a supermassive black hole? Only an array of radio telescopes the size of the Earth... That's because even the biggest and nearest of these cosmic monsters are extremely elusive – dark denizens in the blackness of space.

These shady inhabitants of our cosmos strain science to its limits. Their extreme gravity is a crucial test for Einstein's theory of General Relativity – it's so intense that not even light can escape. "Once objects fall in, they're lost forever," observes Shep Doeleman of the



A computer model of the black hole at the heart of M87, based on data from EHT's first three dishes

PHOTO: SHEP DOELEMEN

➔ MIT Haystack Observatory in Massachusetts. “It’s an exit door from our Universe. You walk through the door, you’re not coming back.” The end of the road is the ‘event horizon’, where in-falling matter reaches a sizeable fraction of the speed of light and succumbs to the black hole’s gravity. And Doleman is building a telescope that within three years will reveal the event horizon for the first time; a telescope that will dwarf the famous Jodrell Bank dish that’s the setting for this month’s *Stargazing Live* on BBC Two.

Black holes were first discovered in the 1970s, by satellites searching for X-rays from energetic objects in space. This highlights the key to finding black holes – they’re messy eaters. “Not everything can squeeze into a black hole. The result is a cosmic ‘traffic jam’ in which gas and dust build up, creating a flat pancake of matter known as the accretion disc,” says Doleman. The accretion disc, visible both in X-rays and radio waves, is the smoking gun that gives the black hole away.

The idea of black holes is not new. Flashback to Thornhill, Yorkshire, in 1783. Reverend John Michell – local vicar and a former professor of geology – presented a paper to the Royal Society on a very strange notion indeed: that a massive star could have such strong gravity that even

light wouldn’t be able to escape it. The star would consequently be unlike any seen in the night sky – it would be dark.

The first black holes to be detected were those that resulted from the deaths of massive stars in supernova explosions. They weighed in at some 10 times the mass of the Sun – the collapsed remains of the imploded core of the dead star. But astronomers started to realise that there were much bigger fish out there.

Major galaxies are in fact built around so-called ‘supermassive’ black holes. These monstrous beasts are gigantic – the most massive known, in the galaxy OJ 287, weighs the equivalent of 18 billion Suns. The gravity of these black holes powers

“Once objects fall into a black hole, they’re lost forever. It’s an exit door from our Universe”

Shep Doleman of the MIT Haystack Observatory on what makes black holes so fascinating

the energetic accretion disc and shoots off jets of gas at almost the speed of light. By studying speeding stars at the centre of our own Galaxy, astronomers have concluded that even the apparently placid Milky Way harbours a massive black hole, known as Sgr A* (pronounced ‘Sagittarius A-star’).

To home in on this dangerous dweller of the cosmos in detail will require the Event Horizon Telescope (EHT). This array of radio telescopes will eventually stretch from Hawaii, California, Arizona, Mexico and Chile to France, Spain and Antarctica.

The biggest challenge is a black hole’s size, or rather the lack of it. “In order to even think about imaging a black hole, you need to devise a way to get extraordinary angular resolution, because black holes are so compact,” explains Doleman. “Sgr A*, the black hole at our galactic centre – which is four million solar masses – would look as big as a golf ball on the Moon!”

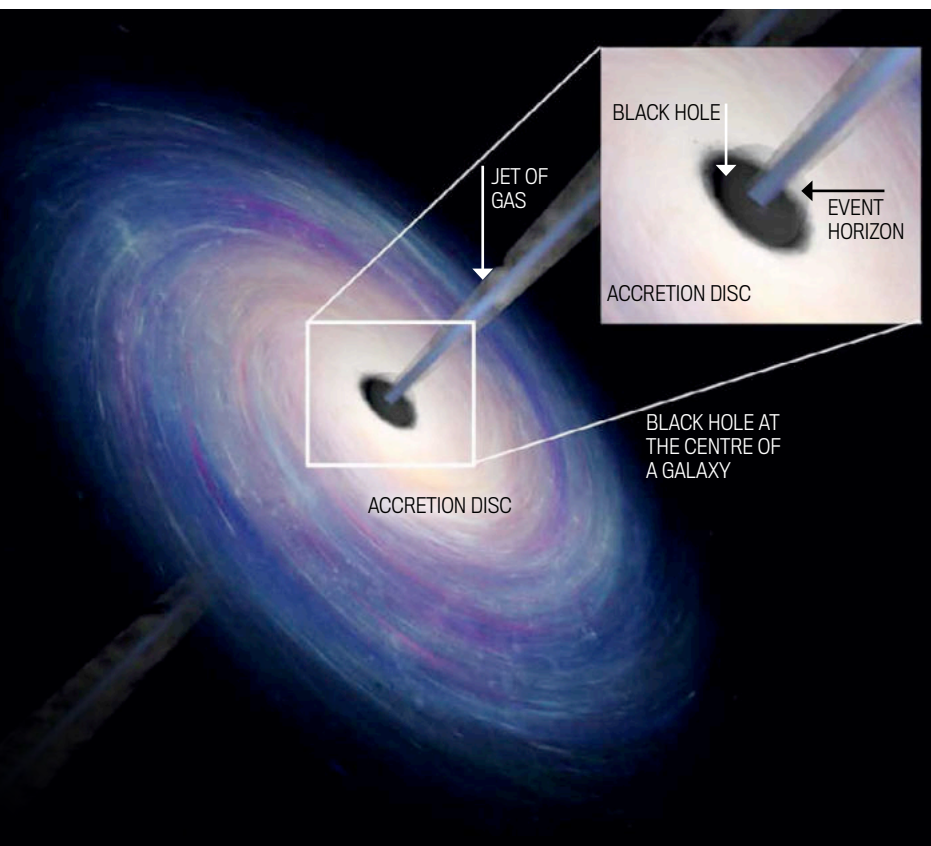
BIGGER AND BETTER

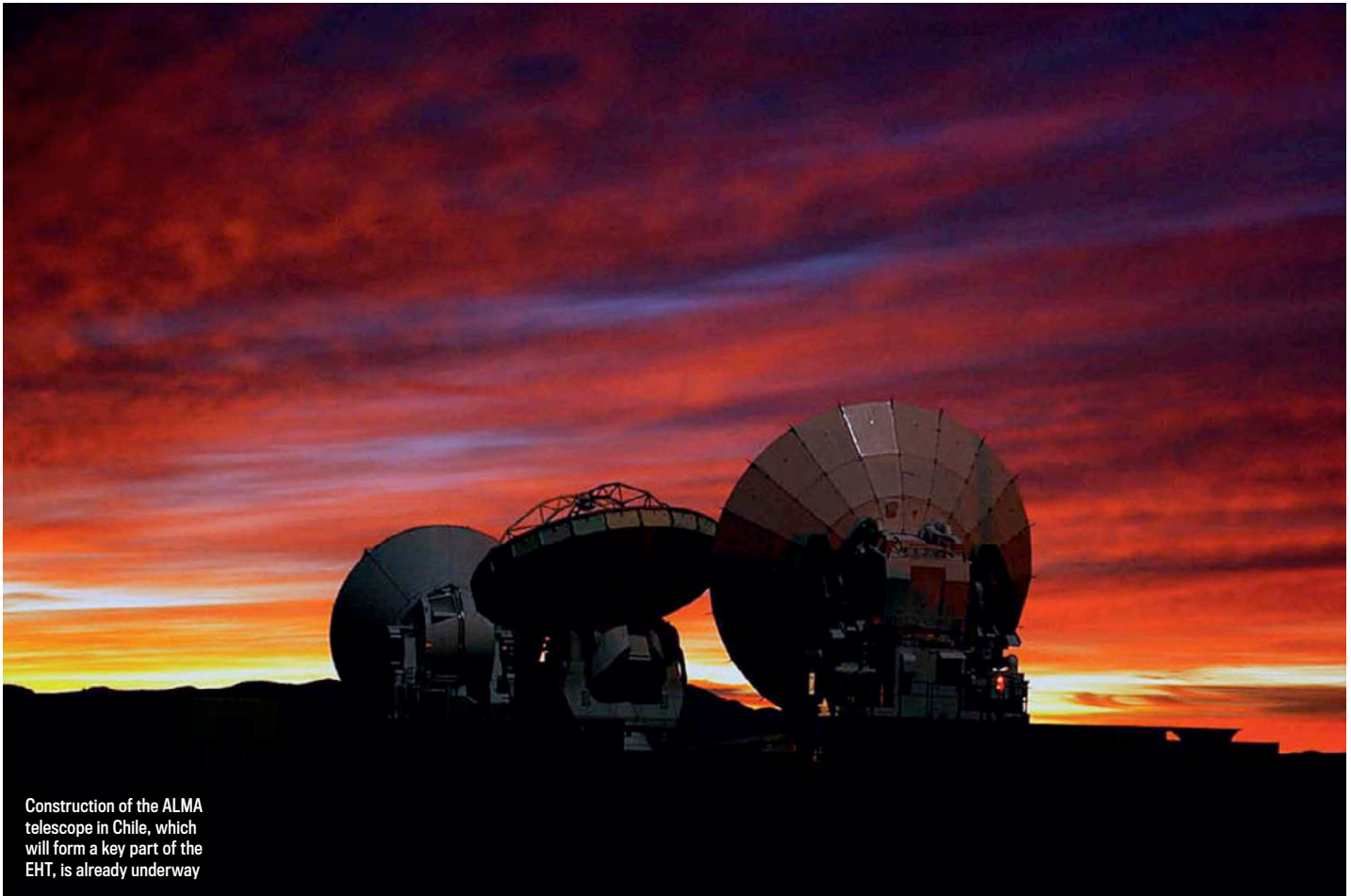
The trick is to link up a network of radio telescopes, using a technique called interferometry, over large distances to make a mega-dish. But to capture that central, supermassive black hole will require a special technique. “Very Long Baseline Interferometry (VLBI) could

ANATOMY OF A BLACK HOLE

They’re incredibly small and dense, but there is more to them than you might think

You can regard black holes in two ways: either as massive collapsed objects where gravity is so strong that not even light can escape, or – according to Einstein’s General Theory of Relativity – as ‘dents’ in the fabric of space, which he saw as being rather like a flexible rubber sheet. They warp space-time, distorting light around them and causing time to stand still. Physically, a black hole’s trademark is its accretion disc: a vortex of superheated matter, pulled in by gravity, that swirls into the hole before disappearing at the ‘event horizon’ at the speed of light. At the last gasp, the doomed matter spews out energetic magnetised jets of gas. Then it heads for the central ‘singularity’ at the heart of the black hole – an object of infinite density. What happens next is a still disputed, but some astrophysicists believe that the matter might end up in another universe.





Construction of the ALMA telescope in Chile, which will form a key part of the EHT, is already underway

reach such resolution,” says Doeleman. “We know we can use VLBI to observe a black hole near the event horizon, where the unique effects of strong gravity become apparent.”

Radio waves offer a double whammy when it comes to finding black holes. They cut through the dust that blocks light from the crowded downtown regions of galaxies. And – unlike light – it’s possible to combine radiation received by radio telescopes that are continents apart (see ‘Building a black hole telescope’, p64).

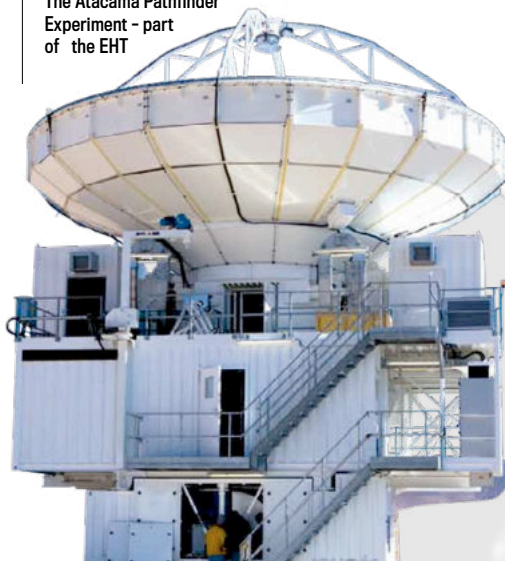
Dr Tom Muxlow, a galaxy expert at the Jodrell Bank Centre for Astrophysics, is awed by the potential of the EHT. “Because radio waves have much longer wavelengths than those of visible light, it takes arrays with spacings of over 200km to produce images of comparable resolution to the Hubble Space Telescope – whose mirror is 2.5m across. By comparison, the EHT will have an aperture of around 11,000km – making its resolution 2,000 times greater than the Hubble Space Telescope!”

By pushing to the shortest wavelengths, around 1mm, the EHT

has a great eye for detail – making it the first telescope that can see something as small as a black hole. But it’s not just about linking telescopes. According to Doeleman, “the biggest breakthrough so far has been our ability to harness rapidly evolving industrial trends that allow us to process torrents of data.”

Most radio telescopes tune into a particular wavelength, like selecting a station on your radio. But that throws away most of the radiation that’s coming

The Atacama Pathfinder Experiment – part of the EHT



in from space. The EHT telescopes use new technology that pick up a wider range of wavelengths, or ‘bandwidth’. “With modern integrated circuits, we have increased the bandwidth by factors of eight to 16 over what was used just five years ago,” explains Doeleman.

The team at MIT has already used the first three dishes in the EHT array – based in California, Hawaii and Arizona – to probe the black hole at the centre of M87. This massive elliptical galaxy – which dominates the Virgo Supercluster, of which our Local Group of galaxies is a member – harbours a supermassive black hole at its core.

“We didn’t actually make an image,” explains Doeleman. “We were able to measure the relativistic jet that’s produced by the monster black hole at the heart of M87. I say ‘monster’ because it’s about 2,000 times more massive than Sgr A*.”

Doeleman continues: “We need Einstein’s theory of gravity to make sense of what we see. The black hole must be spinning. And the disc structure predicted using Einstein’s equations is dependent on the spin of the black

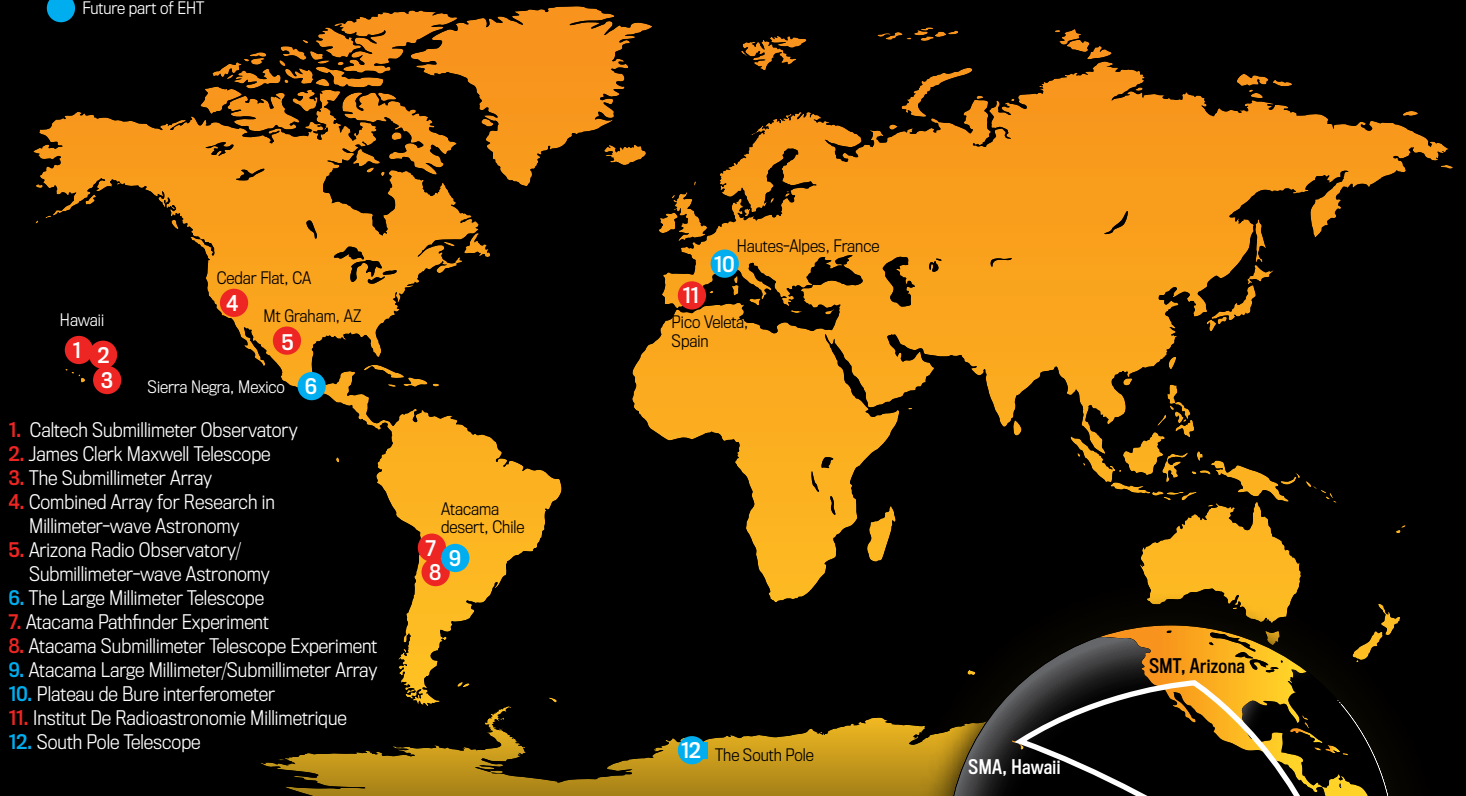


BUILDING THE EVENT HORIZON TELESCOPE

How to make an instrument the size of the planet

KEY

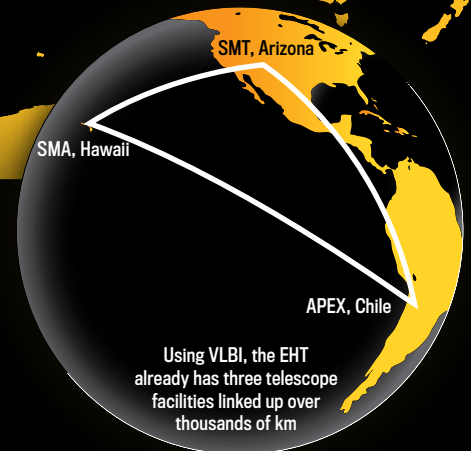
- Telescope in operation
- Future part of EHT



THE VIRTUAL DISH

The Event Horizon Telescope is the ultimate in Very Long Baseline Interferometry (VLBI) – linking together separate radio telescopes to create a ‘virtual dish’ as wide as the distance between the farthest pair of telescopes. The array must also contain telescopes at a range of smaller separations, to fill in the middle

of the virtual dish – otherwise the final image will be distorted. British astronomer Martin Ryle at the University of Cambridge pioneered interferometry in the 1950s: his largest telescope was 5km long, on the track of the old Oxford–Cambridge railway. The ‘very’ in VLBI refers to connecting telescopes that are located on different continents, thousands of kilometres apart.



HOW IT WORKS

All the telescopes observe the black hole at the same time, so they are simultaneously sampling the same radio waves. Each scope has an aerial that picks up the radiation, connected to a very sensitive amplifier cooled to -269°C to reduce noise from stray electrons. Fibre-optic cables feed the signal to the control room, where it’s time-stamped by the ‘ticks’ from a hydrogen maser clock and recorded onto hard drives that are flown back to the EHT’s nerve-centre at the Haystack Observatory. Here, Shep Doleman and his team use the time-stamps to synchronise all the recordings. They then combine the signals as if the far-flung telescopes had actually been connected during the observations, creating the view as seen with a telescope as wide as the world.



“There’s a three Earth-mass cloud of gas/dust that will crash into Sgr A* starting this year”

Shep Doeleman explains how a great photo opportunity awaits the EHT once it’s working

→ hole. This result delighted us, because it means we can turn the EHT on M87, and ask how black holes launch galactic-sized jets. We couldn’t have asked this question a few years ago.”

Science will be boosted still further when the EHT measures the polarisation – the orientation of the vibrating radiation – of the radio waves from M87. This will reveal the direction of magnetic fields around the black hole and tell us how the jets are accelerated. “For the first time, we will be able to test our theoretical models regarding the intensely wound magnetic fields,” says Muxlow.

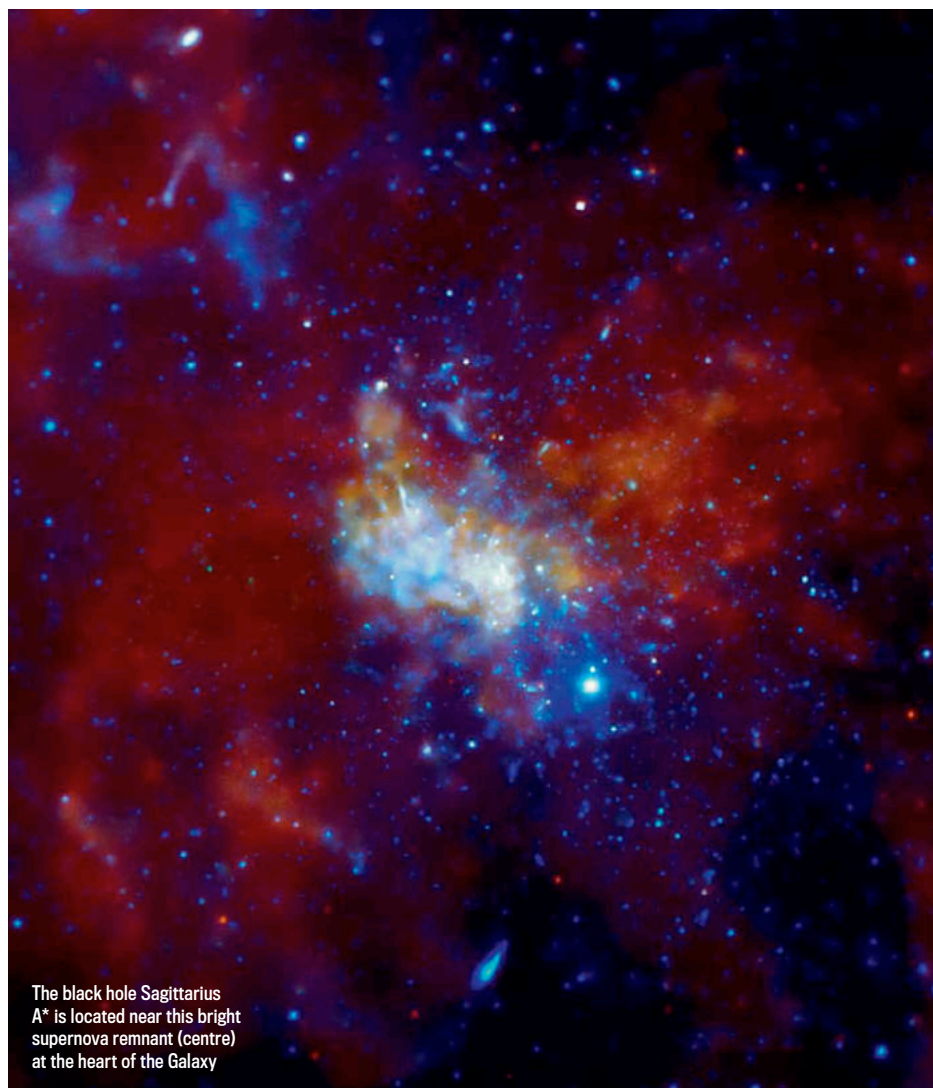
THE BIG PICTURE

The EHT is growing fast, and there’s about to be a major British contribution in the shape of ALMA – the Atacama Large Millimeter/submillimeter Array of 66 dishes, currently being built as an international collaboration in Chile. Tom Muxlow enthuses about its potential. “Plans are advanced which will allow astronomers to phase together the array of 12m ALMA antennae, located in the Chajnantor Plateau in Chile – at a height of 5,100m – to become an 84m single dish. This will provide the most sensitive telescope in the world.”

Is it all about location, location, location? “Very sensitive VLBI telescopes are all located at high or very dry sites where water vapour is almost absent,” adds Muxlow. “Water vapour would absorb the incoming radiation from space at such short wavelengths.”

ALMA is good news for the Event Horizon Telescope. “It will boost the EHT’s sensitivity by nearly a factor of 10 in a single stroke,” says Doeleman. “We’re also working on the South Pole Telescope for EHT work – this site is unique in that it can view Sgr A* 24 hours a day.”

The Holy Grail of the completed EHT will be not just to measure the structures, but to create an actual image of the black



The black hole Sagittarius A* is located near this bright supernova remnant (centre) at the heart of the Galaxy

hole and its surroundings. But – thanks to Einstein’s theory of gravity – it won’t simply look like a textbook diagram of a disc swirling around the black hole.

Instead, the black hole should appear as a ‘shadow’. Doeleman explains that the radio waves from the accretion disc “are bent by the gravitational pull of the black hole into a ring around the event horizon. The result is an apparent shadow: a bright ring with a relatively dim interior.”

So when is the EHT team aiming for Sgr A*? “Around 2015-2016,” says Doeleman. “This is especially important now there’s a 3 Earth-mass cloud of gas and dust that will crash into Sgr A* starting this year. This cloud, called G2, should create incredible fireworks in the galactic centre, which would be observable with the EHT. It presents an extraordinary opportunity to observe a black hole digesting a big meal.”

The project has excited fellow scientists. Britain’s Astronomer Royal, Sir Martin Rees – a world-leader in black hole

research – enthuses: “It’s a real step forward to resolve the scale of the black hole.” He looks forward to the further investigation of extreme gravitational fields. One day, those fields may even include M31, the Andromeda Galaxy, which hosts a black hole over 100 million times the Sun’s mass. Hopefully, it won’t be long before we can delve into the heart of these most mysterious of objects. ■

HEATHER COUPER is an astronomer and the co-author of *Philip’s Stargazing 2013*

Find out more



Listen to an interview with black holes expert Caleb Scharf
sciencefocus.com/podcasts

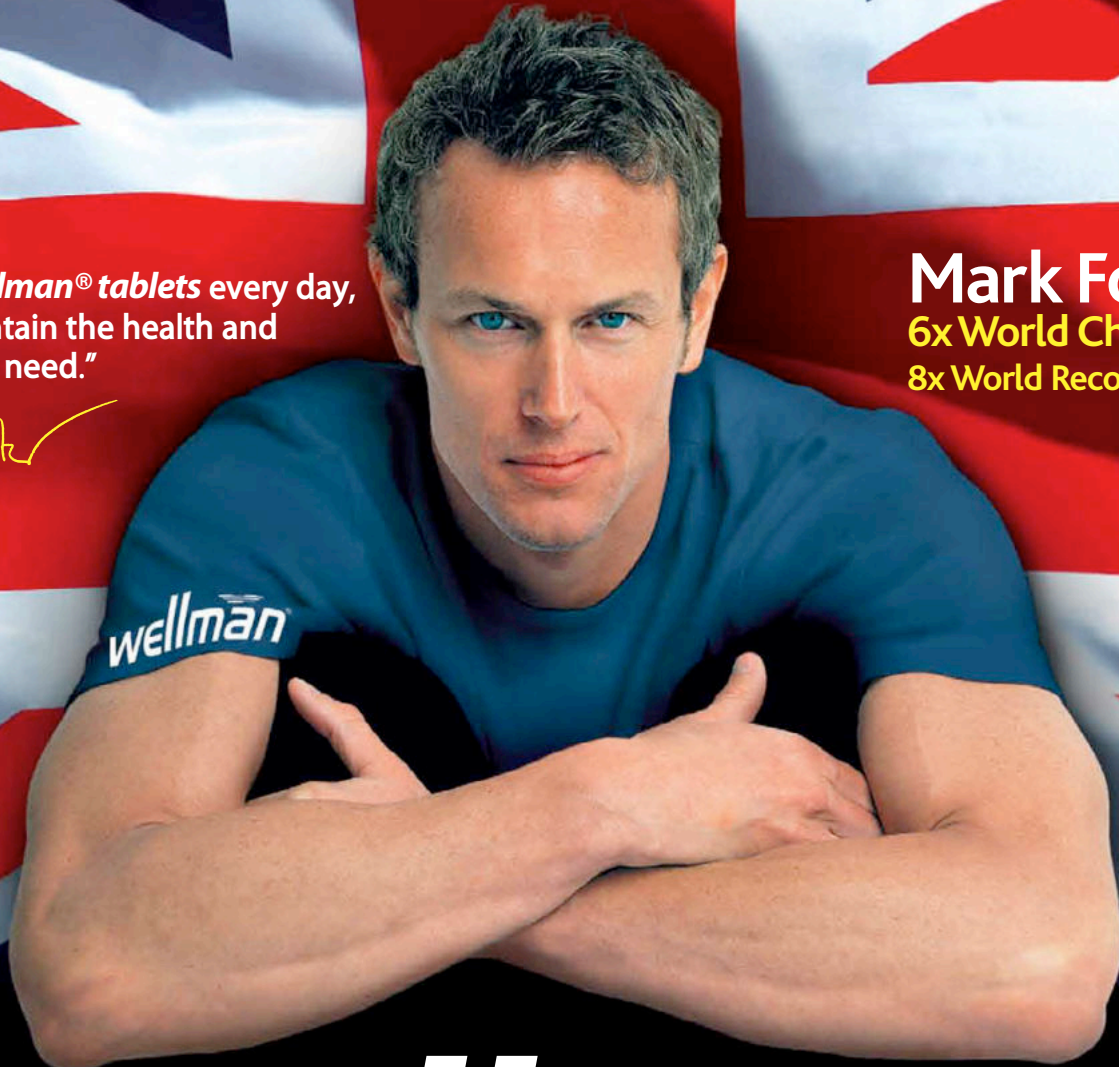


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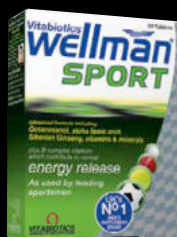
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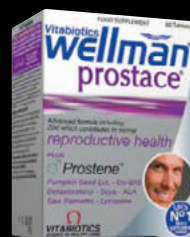
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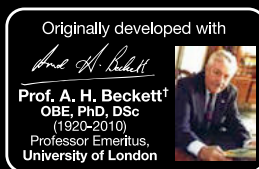


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From Boots, Superdrug, supermarkets, Holland & Barrett, GNC, Lloydspharmacy, pharmacies & health stores.

Vitamin supplements may benefit those with nutritionally inadequate diets. † Professor Beckett is not cited in the capacity of a health professional, but as a product inventor and former Chairman of Vitabiotics.



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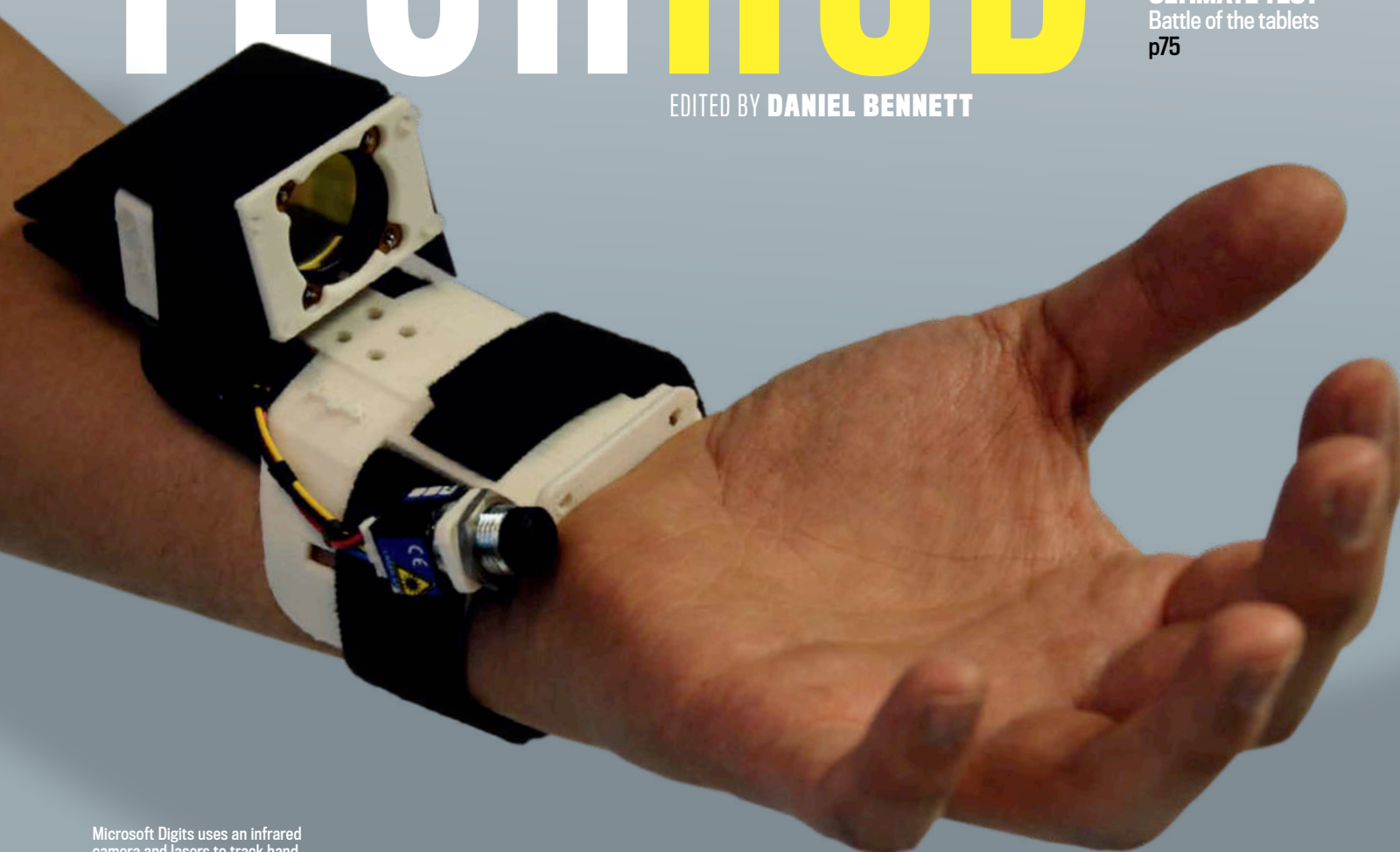
EDITED BY DANIEL BENNETT

➔ THIS MONTH

BILL THOMPSON
Spying by smartphone
p69

JUST LANDED
4G: our verdict
p70

ULTIMATE TEST
Battle of the tablets
p75



Microsoft Digits uses an infrared camera and lasers to track hand movements, enabling you to become a human remote control

ON THE HORIZON

MICROSOFT DIGITS

Microsoft's Kinect system has made it *de rigueur* for Xbox gamers to navigate their way through the console's menus and games by waving their hands at their TV screens. Using this controller-free system already feels like acting out a little slice of science fiction, but now the computing giant is working on the next generation of gesture-based controls.

Inside its R&D labs at the University of Cambridge, Microsoft is looking to change the way we interact with our smartphones, tablets and TVs with a project that's been codenamed 'Digits'. The concept is devilishly simple. You don a wristband, which then tracks your complete hand movements. When ramped up to its full potential, this means the device will allow you to control all the various gadgets around your

home without having to actually touch them.

That could mean turning up the volume on your phone or personal media player by simply twisting your hand, as you turn a volume knob up on a radio or stereo. Or it could mean zooming into web pages or images using the same kind of gestures that you currently use on a touchscreen device.

The technology driving Microsoft Digits relies on an infrared camera and



Digits will harness a system of gestures similar to those used by touchscreen phones



→ an infrared laser line generator. The wristband beams out a grid of infrared lines across the hand. The camera monitors where these lasers land, in order to work out how long the user's fingers are and how they are moving at any given time. An algorithm then converts this data instantly into input for whichever device you're using. Because the technology is squeezed into one wearable, wireless device it can talk to several gadgets as you move around the home. Better yet, it means that you won't have to stay planted in one defined spot for the technology to play nice, unlike its predecessor Kinect.

However, there are drawbacks. Currently the wristband is bulky, and while Microsoft's researchers say they're already working on slimming it down, there are key issues with the tech that will need to be resolved too.

Dr Richard Picking, Reader in Human-Computer Interaction at Glyndwr University says that while it's a fascinating proposition, it's one that's some way from being finalised. "It's still early days and it's not clear how reliable the technology is. How accurately does the camera need to be calibrated? What happens if it gets knocked about or

inadvertently moved? How comfortable is it? Similar innovations, such as dataglove technologies, have failed to find mainstream applications outside the computer games industry. Nevertheless, gesture technology is an exciting area of research. Who is to say that future, reliable, seamless versions of Microsoft Digits won't become popular and truly useful in society?"

As Picking points out, even if Microsoft Digits doesn't become commercially viable, something similar most likely will. It's already part of a growing trend towards gesture tech. Kinect and Sony's PS Move are leading the way in gaming, while the Leap Motion, which tracks the motion and position of your fingers with pinpoint accuracy, could transform how we interact with PCs. But if Digits reaches its full potential, these device-specific gesture tools could just be a bridge to a single-gadget solution for the future.

RESEARCH.MICROSOFT.COM

JOE SVETLIK is a technology news reporter for CNET and TechRadar

TECHOMETER



WHAT'S HOT

GOOGLE BROADBAND

Google has started testing its own superfast broadband service in the US. Residents of Hanover Heights in Kansas City have been experiencing incredible download speeds of up to 1Gbps (1,024Mbps) with Google Fiber. It trounces the fastest, 100Mbps speeds you can currently get in the UK. It means you could download an HD movie in under a minute. Here's hoping Google will pipe its super-quick service into our homes soon.

WHAT'S NOT

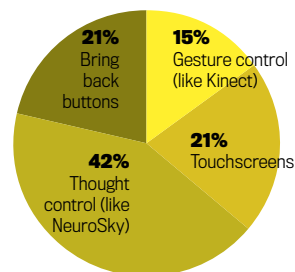
CD-ROM

With Apple shedding the CD drive from its new iMacs, and Windows 8 offering software through an app store, the CD-ROM is heading for extinction. Software, like film and music, is shifting from a physical format to a purely digital one. There could be one hitch, though: UK ISPs already struggle to cope with the traffic caused by iPlayer and LoveFilm, and software downloads would only make matters worse.



READER POLL

How would you like to control your gadgets?





EARLY ADOPTER BILL THOMPSON

Will your next phone snoop on you?

When the US photo-sharing smartphone app Color launched in 2011, it offered a feature that found photos taken by other users nearby. It did this, in part, by using your phone's microphone to look for other users whose phones were 'hearing' the same thing – a band or a conversation in a bar, for example.

Many people, myself included, found the idea a little troubling. It highlighted the fact that a modern smartphone is basically a collection of sensors with a data link to the outside world – a fact that the US Naval Surface Warfare Center has been eager to exploit.

This year it demoed software that secretly turned on a phone camera and took pictures while the phone was being used. The software would then quietly send any images that weren't blank, or too blurred, back to its creators for processing. Test subjects were given the phones and asked to use them normally: taking calls, texting, web browsing and so on. The resulting photos were then stitched together by some very clever software to produce high-resolution 3D models of people's homes, offices, cars and even bedrooms – everywhere anyone might use a phone.

The results were revealing. Lots of personal and confidential information was

clearly visible, including credit cards, bank statements and documents displayed on the screens of their users.

The Navy software was a demonstration, but it exploited vulnerabilities in the Android operating system running on millions of smartphones around the world. It's not hard to imagine it out there for real, perhaps as a Trojan Horse, hidden in a program that looks like a game or a productivity tool.



If you apply good smartphone 'hygiene' and check out any apps online before you download, the chances that your phone will actually start taking secret photographs is very low. But governments around the world seem very keen to pass laws that allow them to monitor and track their citizens. And they would be in a position to get software like this on a phone via the manufacturer or even the network operator, without users being aware at all.

Just last year a US Congressional committee

expressed concern over potential threats to national security if two big Chinese telecoms firms, Huawei and ZTE, were commissioned to build government networks. Their fears are probably overstated, but the idea that a government could force a supplier to build backdoors or spying features into a product isn't unheard of.

If you've got a new smartphone on your Christmas list, I'm not suggesting you should tape over the camera. It's just worth bearing in mind exactly what modern devices can do, and how they might be sharing information without your knowledge or consent.

Besides, this technology isn't only being used for nefarious schemes. A team at the Computer Science and Artificial Intelligence Laboratory at MIT combined a camera with rangefinders, gyroscopes, accelerometers and a Kinect to build a system that creates real-time maps as the wearer walks through a building. But this isn't for spying on people: firefighters can use it to create real-time maps quickly while rescuing any survivors.

It's a technology that's potentially life-saving – it'll just depend on how its owners decide to use it.

Bill Thompson contributes to news.bbc.co.uk and the BBC World Service

COMING SOON

3 MONTHS

NEST

This thermostat remembers everything: every time you turn the heating on or change the temperature, it takes note. In this way, it learns your habits and heats the house to suit. The result is slashed energy bills, and you can control it all from your smartphone. Nest.com



+ **Vileda Virobi** With robot vacuums already scooting around people's floors, it was only a matter of time before a mop-based equivalent came along. Vileda.co.uk

+ Pebble Watch

This smart watch with an E-ink display uses your phone's Bluetooth connection to display your email, Twitter feed and more. Getpebble.com

6 MONTHS

INTEL CLOVERTRAIL

Intel's last generation of chips inspired a whole new species of laptop: the ultrabook. This time, Intel claims that the energy saving and power gains on its next chipset, codenamed Clovertrail, will allow laptops to finally pass the 10-hour battery life mark. Intel.co.uk



+ **Project Glass** Messages, maps and information from the web will all be overlaid on top of your view with Google's new vision for the internet. j.mp/projectglass

+ **Xbox 720** The forthcoming game *Star Wars 1313* has graphics that pundits believe could only be viable on next-gen consoles, signalling the possible arrival of a new console next summer. Xbox.com

9 MONTHS

SAMSUNG GALAXY S4

With its near-field technology, facial recognition and quad-core processor, the Galaxy 3 led the way in terms of smartphone innovation this year. So what can we expect from the annual update next summer? A six-core, graphics-meltingly fast processor, an even bigger screen and, of course, 4G are all on the cards. Samsung.com



+ **iPhone 5S** Apple's yearly smartphone offering will hit shelves in November, hopefully with NFC and a bigger camera. Either way there'll be queues. Apple.com

+ **Apple iTV** An anonymous former Apple employee reportedly told *USA Today* that the company's head designer Jonathan Ive is working on a 50-inch TV. Apple.com

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JUST LANDED

THE 4G NETWORK

The next generation of mobile technology has arrived. **Daniel Bennett** tries out 4G to see if it's the future of broadband...

What is it?

Until recently, data beamed through the air to your mobile travelled a lot more slowly than data sent via cables in to your home. But that's not the case anymore, thanks to the 4G network. This new network can send data to your phone at around 12Mbps, which is on a par with home broadband speeds. In practical terms, that means it transfers 1MB of data per second. The size of the average film for a mobile phone is 574MB.

In the UK, this speed boost comes from a technology known as MIMO (Multiple In Multiple Out). In essence, MIMO-equipped phones and masts send packets of data to each other over multiple connections, rather than just one, increasing the amount that can be sent per second.

How fast is it really?

Everything Everywhere (EE, the former T-Mobile and Orange) is the only network offering 4G right now. It says its network offers average speeds of 8-12Mbps. As it turned out, 12Mbps was actually the minimum speed we enjoyed: during a week of testing in Bristol we reached up to 30Mbps and averaged about 15Mbps. By comparison, our 3G phone now seemed sluggish, averaging 4Mbps.

4G test phones (L-R): HTC One XL, iPhone 5, Huawei Ascend P1

On all the phones we trialled, including an HTC One XL, an iPhone 5 and a Huawei Ascend P1, web pages loaded almost instantly. Compared to 3G it amounts to a difference of split seconds, but you soon become acclimatised to these new heady speeds. Where you'll really start to notice the speed gains, though, is in downloading big files.

We downloaded a full movie in just under 10 minutes, something that wouldn't have been practical before. Better yet is the video calling experience. Using Skype or Facetime on a smartphone has only been practical over Wi-Fi until now, but 4G speeds let you make video calls smoothly wherever you have a signal. And if you're a gamer, your ping – the time in milliseconds for data to be sent from phone to server – is fast enough to allow for seamless online gaming on the move.

What's the catch?

Price. EE's basic 4G mobile data plan costs £36 per month over two years. This gives you unlimited calls and texts, but only 500MB of data to use each month. Go over this limit and you'll incur extra charges. The trouble is, if you use 4G as intended you could chew through 500MB in just eight minutes! Even EE's largest plan, giving you 8GB of data for £56 per month, could be used up in two hours, and on its smallest plan you wouldn't even be able to stream a film.

To soften the blow, EE is offering customers a free film rental every week, on top of your data allowance. So if you limit yourself to web browsing and don't stream videos you should be fine – but that's not what 4G should be about. It should have been the mobile internet unchained, with all the bells and whistles, but with such restrictive data plans that

simply won't happen. There was an opportunity here to reimagine how we think about and charge for data, and it's been missed.

Should I get a 4G contract?

There will always be early adopters who want the newest, fastest technology, and in that respect EE and 4G won't disappoint. It delivers the speeds it promises and more. But for most, the cost will be too high and the monthly data limits too low. There's also the fact that 4G is currently only available in 11 UK cities.

But it was a bind, after a week of testing, to go back to 3G, with its stuttering video and stalling web pages. So if and when a data plan more suited to our wallets and our internet usage does arrive, we'll be first in line. In fact, we'd consider ditching our home connection altogether to go fully mobile.



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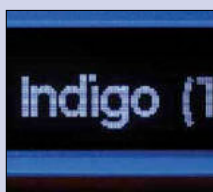


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It takes just two button presses to load a CD and just 3-4 minutes to rip it onto the internal hard drive. So you can comfortably load between 20 and 30 in an evening.



Vinyl and Cassettes?

You can record both onto the JB7 as if it were a very large tape recorder. All you will need is a 3.5mm stereo jack, twin phono lead, adapter or connector.



Album and track names automatically added.

Once you've downloaded a CD the Brennan automatically checks its massive 3 million database to confirm the album title and track names.



Keep your music safe.

Just in case of a breakdown, the JB7 enables you to back up your entire music collection onto an external hard drive so you don't have to spend time re-loading.

The face behind the Brennan JB7 range.

Martin Brennan, who designed the JB7, has worked with Sir Clive Sinclair and Lord Alan Sugar and has designed over 20 silicon chips in his career. He was a real pioneer in the computer games industry - he played a central role in the design of the worlds first 64 bit games computer.

Visit the online shop at **www.brennan.co.uk**

The 2012 JB7 links to selected iPods and MP3 players only. Check website for compatibility.

A word about copyright "In 2006 the record companies said unequivocally that they are happy for you to load your own CDs onto a hard disk but the Advertising Standards Authority have asked us to tell you that it is unlawful to copy material without the permission of the copyright holder."

brennan

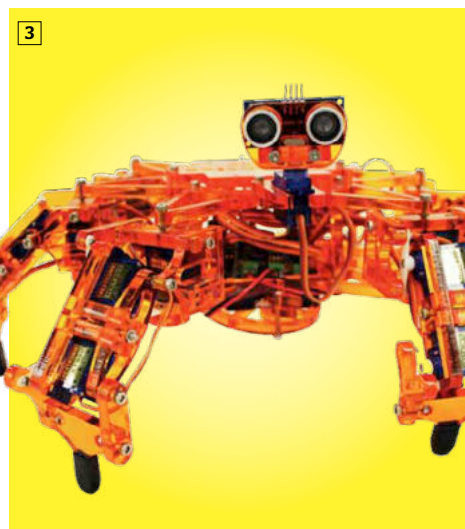
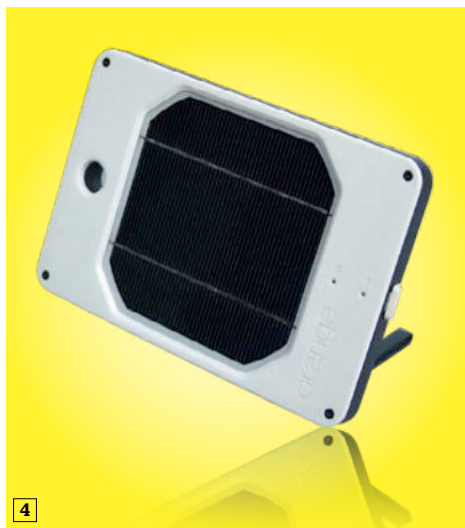
The new sky™ wifi smartpen



It's time your ideas, memories and inspiration worked for you, any time and anywhere. What starts on paper, doesn't have to stay there. Everything you write and hear is recorded and wirelessly sent to your personal Evernote® account for play back on nearly any device.




1

2

3

4

5

6

APPLIANCES OF SCIENCE

1 HOT HANDS

Fend off the winter chills with the help of some techy gloves. Each finger and thumb of the Powerstation Gloves is lined with a heating element. These get their power from small rechargeable battery packs sewn into each glove that last for up to three hours – perfect for a long winter walk. They're likely aimed at bikers, but that shouldn't get between you and some toasty mitts. **Rohan Powerstation Gloves**
Rohan.co.uk; £125

2 PEN PAL

Write with this pen on any surface and your notes are automatically saved as a digital file. Then, when you come into Wi-Fi range of your PC, tablet or phone, those files will automatically transfer to your hard drive. And if you use Evernote, the files will be sent to the cloud where you can access them later from any of your devices. What's more, there's a mic at the top, so it'll act as a dictaphone too. **Livescribe Sky Wifi Smartpen**
Livescribe.com; £159

3 BUG BOT

Ever dreamed of creating your own six-legged mechanical creature? No? Well it's all we think about at *Focus*. Hexy the Hexapod is a cheap, DIY option for budding roboticists. The kit comes with ultrasound-powered eyes, an Arduino microcontroller and 20 servo motors for moving Hexy's limbs. Once you've put it together, you can command the 'bot using the simple Python coding language. **Hexy the Hexapod**
Arcbotics.com; \$250 (£160)

4 SOLAR CELL

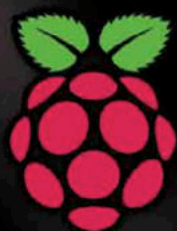
This is the Bear Grylls of solar chargers. It's sand-, shock- and waterproof so it's prepared for all eventualities. One hour under the Sun equates to roughly two hours' worth of talk time on your mobile phone. It'll charge most mobile devices, including tablets, cameras and MP3 players, but its wattage won't quite be enough to power a laptop. **Joos Orange**
Solarjoos.com; \$149 (£93.42) plus P&P

5 CAFFEINE KICK

Use some science to extract the maximum amount of precious caffeine from your coffee. The lower jug is filled with water and heated. As it boils the steam passes through the ground coffee beans, before condensing and falling back into the lower jug again. The crucial component here is the Pebo's vacuum seal, which ensures that none of the coffee vapour escapes. And it looks beautiful too. **Bodum Pebo**
Bodum.com; £55

6 TRAINING WHEEL

We thought stabilisers already did a pretty good job of steadying a bike when its rider wasn't quite up to it, but we were wrong. This wheel, which comes in a variety of sizes for different bikes, is fitted with a gyroscope that keeps the whole bike level in spite of the rider's weaving. Since it comes with three stability settings, the novice rider can learn to balance the bike in gentle stages. **Gyrowheel**
Thegyrobike.com; \$99 (£61.90) plus P&P



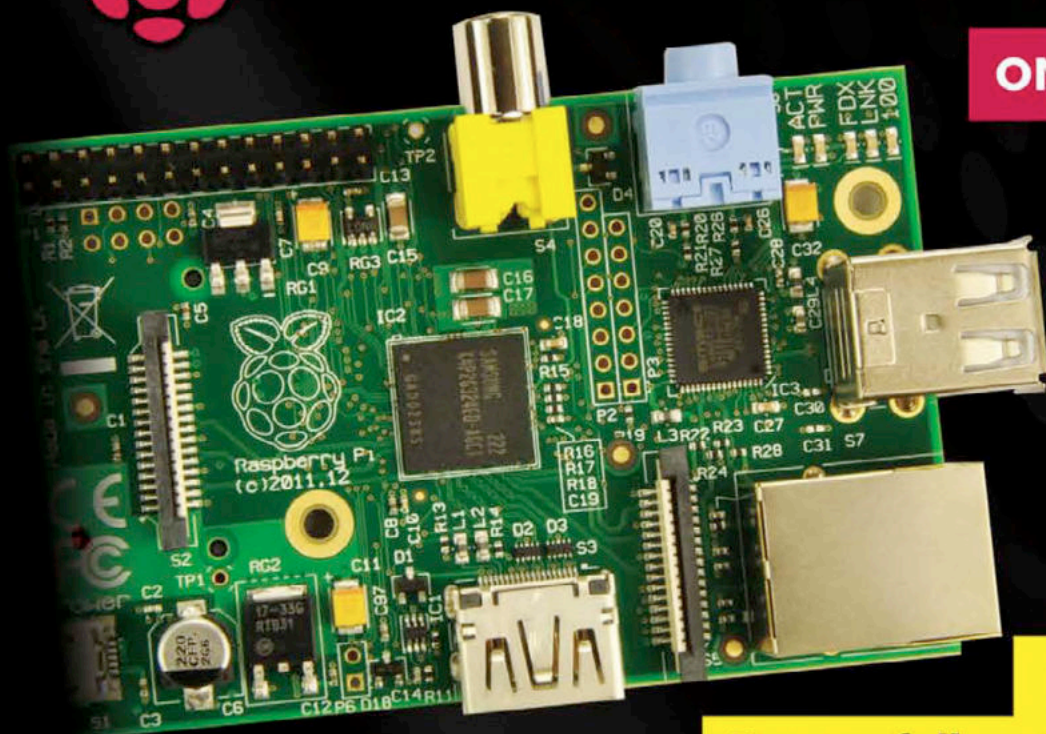
Raspberry Pi

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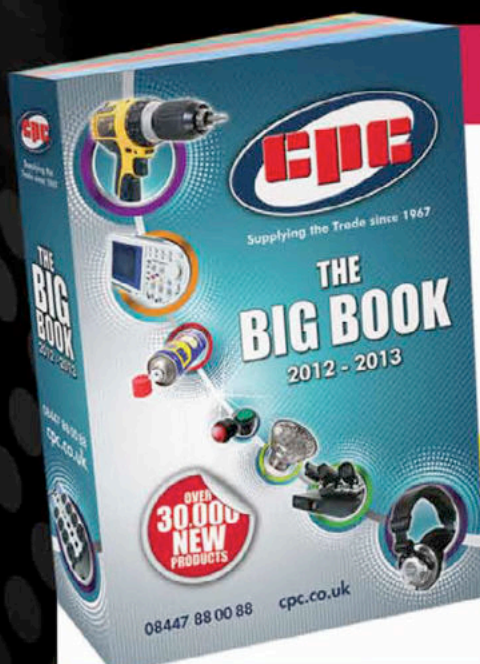
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The Raspberry Pi is a credit-card sized Linux computer that connects via HDMI to your TV or monitor. This diminutive computer is capable of anything a desktop PC can do including spreadsheets, word-processing, games and the output of high-definition video.

- 700 MHz ARM11 ARM1176JZF-S core • 512MB RAM • Supports XBMC • Runs Raspbian optimised version of Debian Linux OS
- Broadcom VideoCore IV, OpenGL ES 2.0, OpenVG 1080p30 H.264 high-profile encode/decode • Boots from SD card
- 2x USB ports, 10/100 wired Ethernet RJ45, HDMI output, 3.5mm stereo audio, composite video, GPIO header



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ULTIMATE TEST **TABLET WARS**

The original iPad is no longer alone, with new sizes and makes of tablet computer available. **Jack Schofield** gets hands on with the different options

Jack Schofield is *The Guardian's* computer editor



7"

TABLETs ARE COMPANION devices that fit somewhere between two things that you probably already own: a mobile phone and a laptop. Like smartphones, they enable you to 'snack' on information, do your social networking, watch videos and play games, but on a bigger, more legible screen. A 7-inch model fits this bill perfectly. The nice things about 7-inch tablets are that they are mostly cheap, and they are so portable that you can put one in a jacket pocket. But their screens are a little on the small side if you want to create content, such as editing documents and photos, rather than just consume it.

OR

10"

TABLETs WITH 10-INCH screens provide even more area for consuming information around the house, but a bigger display usually results in a heavier, less portable and more expensive device. A 10-inch tablet won't fit in a pocket and you probably won't want to take it everywhere, unless it means you can leave your laptop behind. Buyers of 10-inch tablets therefore tend to have some interest in creating content – where a big screen helps. With that in mind, we tested two tablets that come with detachable keyboards and mousepads for added productivity. ➔



7" AMAZON KINDLE FIRE HD

£159, Amazon.co.uk

→ GIVEN THE FIRE HD's price, I was surprised at just how good it was. It feels well-made and the 7-inch screen looks bright and colourful. It's also the easiest tablet to use if you're not familiar with them. Amazon uses the Android operating system, but hides its complexity under a simple front end that is more like a Kindle eReader. You just touch the word you want on the menu along the top to select Shop, Games, Apps, Books, Videos and so on. Content can be stored on the device or in the cloud on Amazon's computers. As with Kindle eReaders, it's best to get your own content on board by emailing it to your cloud address, but I had no problems downloading files from Microsoft SkyDrive.

YouTube clips played by setting the browser to 'Mobile' mode, while BBC videos worked after downloading the BBC Media Player from Amazon. There's no BBC iPlayer, no access to the Google Play store (formerly Android Market), and if you download apps outside Amazon, there's no guarantee they'll work.

The Kindle Fire HD is designed for content consumption, and specifically Amazon content, including Hollywood movies. The first word on the menu is Shop, so if you're an Amazon fan, the Kindle Fire HD is great, but limited.

FOCUS RATING ■■■■

BEST FOR PRICE

Amazon sells the Fire at close to break-even price. Despite this it still has a great resolution screen, solid build quality and more ports than the iPad mini.

BEST FOR APPS

The number and quality of tablet-dedicated apps is the main draw here, while iOS 6 is a polished interface that's a breeze to use. Price and lack of ports could put some off.



OR



KINDLE FIRE HD

PRICE: £159
DISPLAY SIZE: 7-inch
RESOLUTION: 1,280 x 600 pixels
WEIGHT: 395g
FRONT CAMERA: Video only, 720p
BACK CAMERA: None
PORTS: Micro USB, Micro HDMI, headphone jack
BATTERY: 11 hours

IPAD MINI (Wi-Fi model)

PRICE: £269
DISPLAY SIZE: 7.9-inch
RESOLUTION: 1,024 x 768
WEIGHT: 308g
FRONT CAMERA: 1.2MP, 720p
BACK CAMERA: 5MP, 1080p
PORTS: Headphone jack, Lightning connector
BATTERY: 10 hours

7" APPLE IPAD MINI

£269, Apple.com/uk

→ THE IPAD MINI is surprisingly small but beautifully formed. It's much thinner and lighter than the 7-inch Kindle Fire HD and has a bigger (7.9-inch) screen, in spite of being roughly the same size. In fact, the iPad mini is basically a second-generation iPad 2 shrunk to jacket-pocket size, and runs the same content in the same way. Yes, it lacks the new iPad's renowned 2,048 x 1,536-pixel retina screen display, but having less weight and extra portability is a good trade-off. The mini only does 1,024 x 768 pixels, which sounds worse than the Fire HD's 1,280 x 800, but side by side, the mini provides a bigger and better picture with more natural colours.

It also comes with the polished iOS 6 operating system and the browsing experience is exceptional for a tablet. All the videos I tried on YouTube and the BBC website worked first time, which is the reverse of my experience with the Fire HD. However, some things wouldn't work because the iPad can't play Adobe Flash. Of course, the iPad mini is also linked to a shop - Apple's App Store - and this offers by far the biggest number of really good tablet apps. The drawback is the price, which starts at £269, though that's cheap by iPad standards.

FOCUS RATING ■■■■■

10" MICROSOFT SURFACE RT

£399 (Touch Cover £99.99), Microsoftstore.com

→ SURFACE RT IS a gorgeous piece of hardware, with a big and strikingly good 10.6-inch widescreen. It's so robust that the ex-head of Windows added some wheels and used one as a skateboard. It's also thin (9.4mm) and light (680g) for a device that works as both a tablet and a laptop. As a tablet, Windows RT can do anything the iPad can do... except run 275,000 apps because they aren't available. Add a 3mm Touch or 6mm-thick Type keyboard/cover, open the built-in kickstand, and it's great for running the full Internet Explorer 10 browser and Microsoft Office programs. Note that the 32GB model is really 16GB because Windows and Office take up half the storage space. You can also plug in microSD cards and

most USB peripherals, including printers, making it much more versatile in connectivity than an iPad.

While not everyone will like the 'glanceable' Live Tile interface, it's very functional and makes the iPad look old fashioned. However, Surface RT uses an ARM processor, and a new Intel Atom chip would probably perform better. It would also run old Windows programs written for XP and Windows 7, which Surface RT can't do.

As someone who lives in Office, I fancy buying a Surface RT, but I'll probably wait to see the Intel Core i5 version, due next year.

FOCUS RATING ■■■■■

BEST FOR BUSINESS

Adding a keyboard for £99 makes this a pricey option. But with Office software and a healthy selection of ports, this is a great lightweight workhorse.



OR

MICROSOFT SURFACE RT

PRICE: £399

DISPLAY SIZE: 10.6-inch

RESOLUTION: 1,366 x 768

WEIGHT: 680g

FRONT CAMERA: 720p

BACK CAMERA: 1MP, 720p

PORTS: USB, microSD, HDMI,

headphone jack

BATTERY: 8 hours

ASUS TRANSFORMER

PRICE: £379

DISPLAY SIZE: 10.1-inch

RESOLUTION: 1,280 X 800

WEIGHT: 635g

FRONT CAMERA: 1.2MP

BACK CAMERA: 8MP

PORTS: Micro HDMI, microSD,

headphone jack

BATTERY: 10 hours

(15 with dock)

BEST FOR BATTERY LIFE

A second battery in the keyboard gives it the edge in longevity. Plus the keyboard is included in the price, making it a cheaper option than the Surface.



10" ASUS TRANSFORMER PAD TF300

£379, eee.asus.com

→ CONVERTIBLES TRY TO offer the hands-on ease of use of a tablet and the keyboard-driven productivity of a laptop, and the Asus Transformer has been one of the most successful to date. At first glance, the TF300 version looks and works like a typical netbook. But slide a small silvery catch and, behold, the screen detaches and you are holding an Android tablet with a 10.1-inch widescreen. The hinge system has been redesigned and now works much better than the original, though the case is still a bit squashy. The tablet part is let down by the shortage of decent tablet apps in Google Play. Smartphone apps that look fine on a 7-inch Nexus look weedy on a

10-inch screen, and the Microsoft Office-compatible Polaris software that Asus supplies is dire. The keyboard dock has its own battery, which can recharge the tablet, and the combo runs for a very lengthy 15 hours. Use it on your lap, however, and it tends to tip over, because of the weight of the screen.

The TF300 still looks the best value Android hybrid on the scene, but both Surface RT (with Type keyboard) and the full-size iPad (with Logitech Ultrathin Keyboard Cover) are in a different class, if you're willing to pay the price.

FOCUS RATING ■■■■■

A Startling Memory Feat That *You* Can Do

“How I learned the secret in one evening. It has helped me every day.”

When my old friend Richard Faulkner invited me to a dinner party at his house, I little thought it would be the direct means of doubling my salary in less than two years. Yet it was, and here is the way it all came about.

Towards the end of the evening things began to drag a bit as they often do at parties. Finally someone suggested the old idea of having everyone do a ‘party-piece’.

Finally it came to Peter Brown’s turn. He said he had a simple ‘trick’ which he hoped we would like. First he asked to be blindfolded. Those present were to call out 25 random numbers of three figures each and he asked me to list the numbers in order as they were called.

Peter then astounded everyone by repeating the entire list of 25 numbers backwards and forwards. Then he asked people to request numbers by their position in the list. Instantly he repeated back the correct number in the positions called. He did this with the entire list without making a single mistake.

“There was really nothing to it – simply a memory feat”

On the way home that evening I asked Peter Brown how it was done. He said

there was really nothing to it — simply a memory feat. Anyone could develop a good memory, he said, by following a few simple rules. And then he told me exactly how to do it.

What Peter said I took to heart. In one evening I made remarkable strides towards improving my memory. In just a few days I learned to do exactly what he had done.

The most gratifying thing about the improvement of my memory was the remarkable way it helped me in business and in my social life. I discovered that my memory training had literally put a razor edge on my mind. My thinking had become clearer, quicker, keener. I was fast acquiring that mental grasp and alertness I had so often admired in men who were spoken of as “brilliant” and “geniuses”.

“I can instantly recall anything I want to remember”

Then I noticed a marked improvement in my writing and conversational powers. What’s more my salary has increased dramatically.

These are only a few of the hundreds of ways I have profited by my trained memory. No longer do I suffer the



frustration of meeting people I know and not being able to recall their names. The moment I see someone I have met before a name leaps into my mind. Now I find it easy to recall everything I read. I can now master a subject in considerably less time than before. Price lists, reports, quotations, data of all kinds. I can recall in detail almost at will.

What Peter told me that eventful evening was this: “Send for details of Dr. Bruno Furst’s Memory Course.” I did. That was my first step in learning to do all the remarkable things I have told you about. In fact, I was so impressed that I got permission to publish Dr. Furst’s Course myself.

“Dramatic Improvement”

“I used to be laughed at in the office here about my poor memory and I must admit with a lot of truth. Since I started your Course my memory has improved out of all recognition!”

Mr. J.W. Sullivan, London S.W.2.

My advice to you now is don’t wait another minute. Full details of Dr. Furst’s remarkable Course are available free on request. You could be amazed how a powerful memory can improve your life - send for full details **TODAY!**

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Q&A

YOUR QUESTIONS ANSWERED

BY OUR EXPERT PANEL



SUSAN BLACKMORE

Susan is a visiting psychology professor at the University of Plymouth. Her books include *The Meme Machine*



DR ALASTAIR GUNN

Alastair is a radio astronomer at the Jodrell Bank Centre for Astrophysics at the University of Manchester



ROBERT MATTHEWS

After studying physics at Oxford, Robert became a science writer. He's a visiting reader in science at Aston University



GARETH MITCHELL

Starting out as a broadcast engineer, Gareth now writes and presents *Digital Planet* on the BBC World Service



LUIS VILLAZON

Luis has a BSc in computing and an MSc in zoology from Oxford. His works include *How Cows Reach The Ground*

EMAIL YOUR QUESTIONS TO questions@sciencefocus.com

or post to *Focus Q&A*, Tower House, Fairfax Street, Bristol, BS1 3BN

A total solar eclipse only casts a shadow about 480km wide across the face of the Earth



Q LIZA DENNIS, BRIGHTON

Why are solar eclipses rarer than lunar eclipses?

A SOLAR ECLIPSES ARE not actually rarer than lunar eclipses – in fact, they occur in about equal numbers, usually about two of each

per year. For example, between 2000BC to 3000AD there will be 11,898 solar eclipses and 12,064 lunar eclipses. However, at any one location on Earth, it is much less common to see a solar eclipse than a lunar one. And the reason for this is entirely due to geometry.

A lunar eclipse, when the Moon moves through the shadow of the Earth, is visible from wherever the Moon is above the horizon, which

is over half of the Earth. However, when the Moon appears to move in front of the Sun during a solar eclipse, the shadow cast by the Moon is much smaller than Earth. It's only about 480km (300 miles) wide when cast onto the Earth's surface. Solar eclipses are therefore only visible from within a narrow path across the Earth, making it difficult to get to a location to see one. This is why they are visible less often from any given location. **AG**

PHOTO: CATERS



Q SIMON MEADOWS, POOLE

How can crocodiles survive for so long without eating?

A THEY HAVE A very slow metabolism and are cold-blooded, with tiny brains that don't need to be kept warm. So unlike mammals such as ourselves, they don't need to use a lot of energy maintaining a constant body temperature. They are ectotherms, which means that they get heat from their environment, basking in the Sun when they need to warm up and get moving, or cooling off in water. They can also slow their heartbeat to one or two beats per minute.

Crocodiles have extremely acidic stomachs that enable them to digest bones, shells and even horns to extract as much energy as possible from their prey. And when they've had a good meal they can store a high proportion of the energy it contains. Although most crocodiles eat about 50 meals a year, they can survive a whole year, and sometimes even two or three years, without eating anything. **SB**

Q SAM HOUGH, MONMOUTH

Are there any examples of anti-gravity in nature?

A THE ENTIRE UNIVERSE is in the grip of an anti-gravitational force, often called 'dark energy'. It's this that is currently propelling the cosmic expansion at an ever-greater rate. Its origins are unclear, but calculations suggest that it only has



A force known as dark energy is expanding the Universe

significant effects on huge scales. As such, it seems impossible to harness it as, for instance, a means of propulsion. **RM**

Q AARON HACON, NORWICH

What percentage of my body is the same as five years ago?

A THE IDEA THAT we replace every cell in our bodies every few years is a popular one – but incorrect nonetheless. Fat cells are replaced at about 10 per cent per year, but heart muscle cells turn over at just 1 per cent per year at age 25, declining to 0.5 per cent by age 70. Even if you live to be 100, you'll still have more than half of the heart muscle cells you were born with. The neurones of the cerebral cortex and the cells in the lens of your eye are never normally replaced.

But even though the cells aren't completely replaced, they still change. Molecules are continually exchanged with the environment during ordinary metabolic processes. The water in your body turns over at about 3 litres per day. An adult has around 40 litres of body water, so that's 7.5 per cent per day. After two years, it's statistically unlikely that you have any of the same water molecules. But the calcium in your teeth is locked up forever. **LV**



Ten per cent of your fat cells are replaced every year; if only it was easier to lose a few for good

Q LAURA PARIS, OXFORD

Why do we get cold feet?

A YOUR INTERNAL ORGANS and especially your brain must be kept at a steady 37°C to function properly. So when you start to get cold, the flow of blood to your skin is reduced to keep important parts of your body warm. The mechanism for this involves a protein called RAP1A, which interacts with cyclic AMP, an important biological messenger. Hands and feet are most affected.

However, some people feel the cold more than others. This may be because they are too thin or have insufficient fatty acids in their diet, especially Omega-3. A few people have a much worse problem because they suffer from Raynaud's disease.

When exposed to cold or other stressors, their peripheral blood vessels go into spasm and become very constricted. Their hands and feet not only get extremely cold but can turn blue or yellow and, in the worst cases, become gangrenous. **SB**

Come winter, the warm sock is humanity's greatest invention



QUESTION OF THE MONTH

Q KEITH MAXWELL, BELFAST

Are the qualities of wine affected by vineyard bedrock?

A THIS IS A highly controversial subject among vineyard owners and wine-drinkers alike. Some insist it is important that some wines – such as champagne – can only come from their original geological location, and claim to be able to discern the nature of the soil from the flavour. Cynics argue it's all subjective nonsense.

According to geologist Prof Alex Maltman of the University of Wales, Aberystwyth, if bedrock does have any influence on the flavour of a wine, any effect will be indirect and subtle at most. This is because the roots of most vines aren't long enough to reach down to the bedrock,

and so any effects have to come via the overlying soil. The clay content, porosity and colour of this soil all affect the nutrients that enter the vine, which could in principle change the nature of the resulting wine. But according to Prof Maltman, the evidence for a major role is inconclusive.

While the bedrock debate will continue to rage among wine connoisseurs, there's no such doubt about its role in beer-making. Unlike wine – which is principally made up of the juice from grapes – beer is chiefly water, and so its taste is greatly affected by the geology out of which the brewing water has come. **RM**

Can you pick up notes of granite with a hint of chalk?



WINNER!

Keith wins a copy of *Universe - The Definitive Visual Guide* (DK, £30)



Folkestone's chimneys were toppled by a small earthquake in 2007

Q RAY THOMAS, BY EMAIL

Why don't we get big earthquakes in the UK?

A BIG EARTHQUAKES ARE caused by tectonic plates sliding past each other in a juddering motion. This builds a massive amount of pressure before it's released suddenly and unpredictably. Britain is on the Eurasian plate, about 1,600km (1,000 miles) from the nearest boundary to the west. And it's moving away from the neighbouring plate, so there's no energy build-up. **LV**

Q JOSHUA FINBOW, BRIGHTLINGSEA

Could we ever fuel cars with grass?

A THE CELLULOSE THAT makes up grass can be chemically fermented to produce alcohol, which could propel vehicles. While the economics of growing and converting it don't add up, they just might for special types of grass, such as so-called switchgrass, *Panicum virgatum*, which is prevalent in North America. **RM**

Q SCOTT LLOYD, LEIGH

What's the highest voltage ever produced?

A VAN DE GRAAFF generators produce the highest voltages. Charge is carried by an insulating belt from a lower electrode to another at the top, accumulating across a metallic dome. They can be strapped together to form tandems for even higher voltages. A tandem at Oak Ridge National Laboratory produced the highest ever at 25.5MV (a megavolt is 1 million volts). **GM**

TOP TEN

FASTEST ROAD LEGAL CARS



1. Bugatti Veyron Super Sport

267mph (429km/h)
0-60 in 2.4s
Price tag: £1,486,250



2. Hennessey Venom GT

260mph (418km/h)
0-60 in 2.5s
Price tag: £588,710



2. Koenigsegg Agera R

260mph (418km/h)
0-60 in 2.9s
Price tag: £990,835



4. SSC Ultimate Aero

257mph (413km/h)
0-60 in 2.7s
Price tag: £405,250



4. 9ff GT9-R

257mph (413km/h)
0-60 in 2.9s
Price tag: £430,690



6. Saleen S7 Twin Turbo

248mph (399km/h)
0-60 in 2.8s
Price tag: £343,670



7. Koenigsegg CCX

245mph (394km/h)
0-60 in 3.2s
Price tag: £337,855



8. McLaren F1

240mph (386km/h)
0-60 in 3.2s
Price tag: £601,100



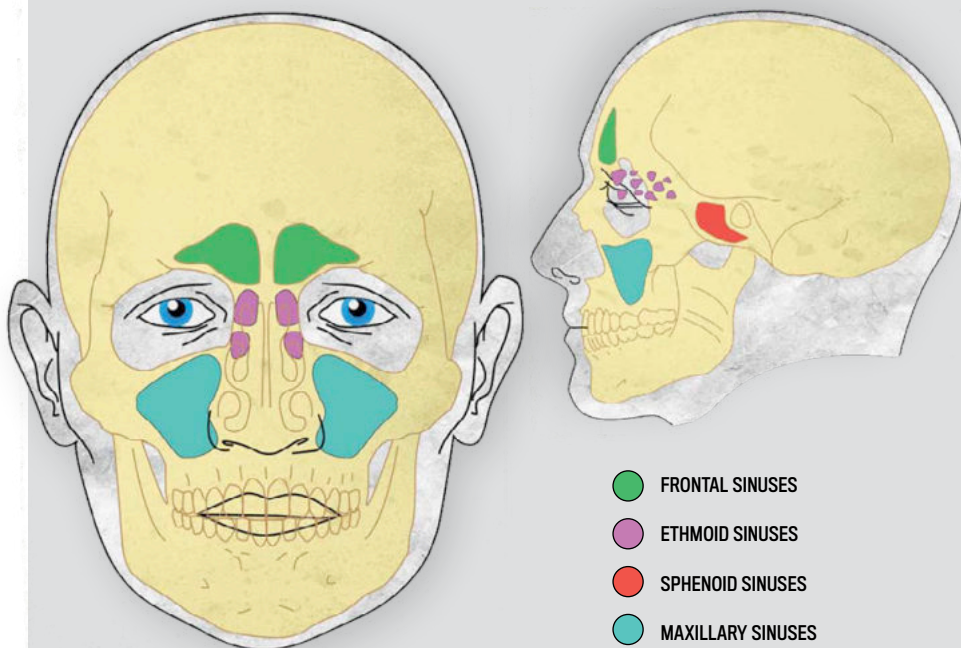
9. Zenvo ST1

233mph (374km/h)
0-60 in 2.9s
Price tag: £759,125



10. Gumpert Apollo

225mph (362km/h)
0-60 in 3s
Price tag: £278,860



- FRONTAL SINUSES
- ETHMOID SINUSES
- SPHENOID SINUSES
- MAXILLARY SINUSES

Q RICHARD EVANS, SELBY

Why do we have nasal sinuses?

A SINUSES, LATIN FOR 'pocket', are air-filled spaces lined with mucus that drains into the nose. We have four groups: maxillary sinuses (around the nasal cavity), frontal (above the eyes), ethmoid (between the eyes) and sphenoid

(behind the ethmoids, the bones that separate the nasal cavity from the brain).

Many functions have been proposed. They may protect our eyes and dental roots from temperature changes, provide a buffer against blows to the face, maintain the temperature and humidity of the air we breathe, balance the weight of the skull, or improve the resonance of our voices. Sadly, we usually only get to know about them when they become infected and blocked, causing a real headache. **SB**

Q SUSIE WALTERS, HEREFORD

Is it true we have three eyelids?

A YOU'RE THINKING OF the nictitating membrane. This is a translucent or transparent membrane that blinks sideways from the inner corner of the eye to the outer. It evolved to protect or wipe the eye without completely blocking vision. Birds, reptiles, fish and some mammals have nictitating membranes. Humans don't, but if you pull the corner of your eye back, you might just be able to see a small fold of skin on the inside. That's the *plica semilunaris*, which is the vestigial remnant of our nictitating membrane. **LV**

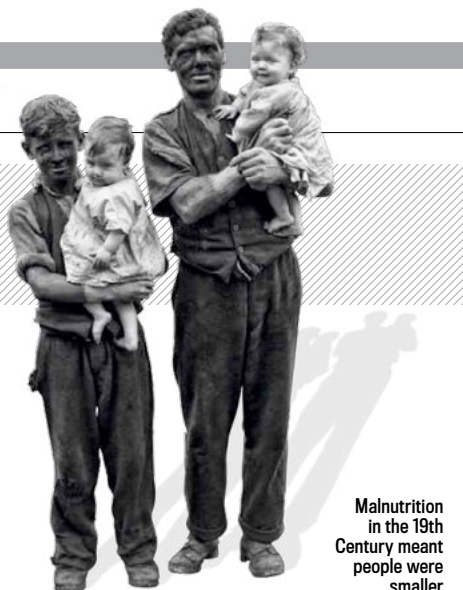


Predators like the Great Horned Owl can clean the eye without blinking

Q CAROLINE SIMMONS, LONDON

Why were people shorter in the past?

A IN THE SHORT term, because they were malnourished. For example, in the mid-19th Century the average height of troops was around 5ft 5 inches (1.65m) in most European countries, 5ft 6 inches (1.68m) in England and over 5ft 7 inches (1.70m) in the USA. Men in all these countries are now much taller. Dutchmen were renowned for being short, but now average 6ft (1.83m). Even now, people in impoverished countries, such as Vietnam and North Korea, are far smaller than in other nations. Yet when they migrate to



Malnutrition in the 19th Century meant people were smaller

richer countries their children grow taller, suggesting the difference is not genetic.

Over longer timespans, the opposite has happened. Fossils from Africa, Asia and Europe show that our ancestors were taller and more muscular than modern people from about 10,000 to 100,000 years ago. After that, skeletons became smaller, probably because of agriculture which, contrary to what you might expect, drastically reduced people's health. Farming meant an increased population living on a far more restricted diet than hunter-gatherers. **SB**

WHAT IS THIS?



KNOW THE ANSWER?

Go to sciencefocus.com/qanda/what and submit your answer now!

LAST MONTH'S ANSWER:

Well done to Colin John Robertson, who correctly guessed the eye of a fruit fly.

Q LORRAINE CROFT, LEICESTER

Is green tea better for you than breakfast tea?



Make mine a green one

A ALL TEA CONTAINS antioxidant compounds called catechins. Black involves oxidising the leaves more so than green, and so black tea is slightly less antioxidant. Studies have shown health benefits for both kinds of tea, including reduced blood cholesterol and lower rates of cardiovascular disease, but green tea seems to have the edge. This may be partly because it's drunk without milk. Black tea with milk has no cardiovascular benefit, according to a 2006 study at Berlin University. In addition, a 2012 study in China found that green tea also repairs age-related damage to brain cells. **LV**

? Did you know?

Hurricane Sandy, which hit the USA in late October, is the largest ever Atlantic hurricane, at 1,800km (1,100 miles) wide

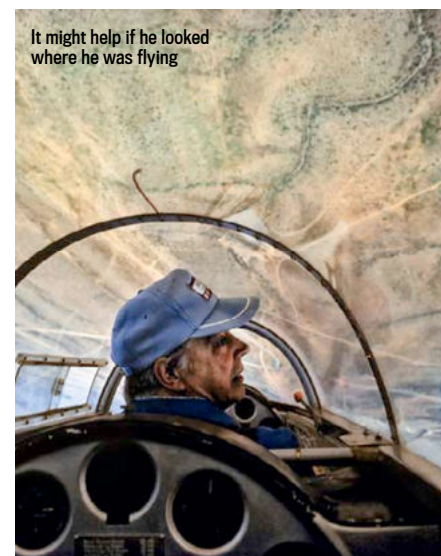
Q ANDREW EVERSETT, DEVON

How do planes fly upside down?

A ALMOST 110 YEARS after the Wright Brothers first flew a powered aircraft, physicists still struggle to come up with a simple explanation for the way that planes generate lift. And it's more complicated when a plane is upside down.

One way to think of lift is to imagine the wing deflecting the stream of air that passes over it, like the jet from a rocket. Airflow tends to adhere to the surface of the wing, and the shape of the wing (the airfoil) deflects the air running over it in a curve that ends up pointing downwards at the trailing edge. By forcing the air to move downwards, you create an upward force on the plane.

When the wing is horizontal, this airfoil deflection is the only source of lift for the plane. But if the wing is tilted upwards, the air that strikes the underside of the wing is also deflected downwards. The steeper the angle, the more the deflected air on the underside contributes to the total lift. When you fly a plane upside down, you just need to make sure that the inverted wings are angled enough that the lift from the underside is enough to compensate for the fact that the airfoil is upside down, and generates some lift. **LV**

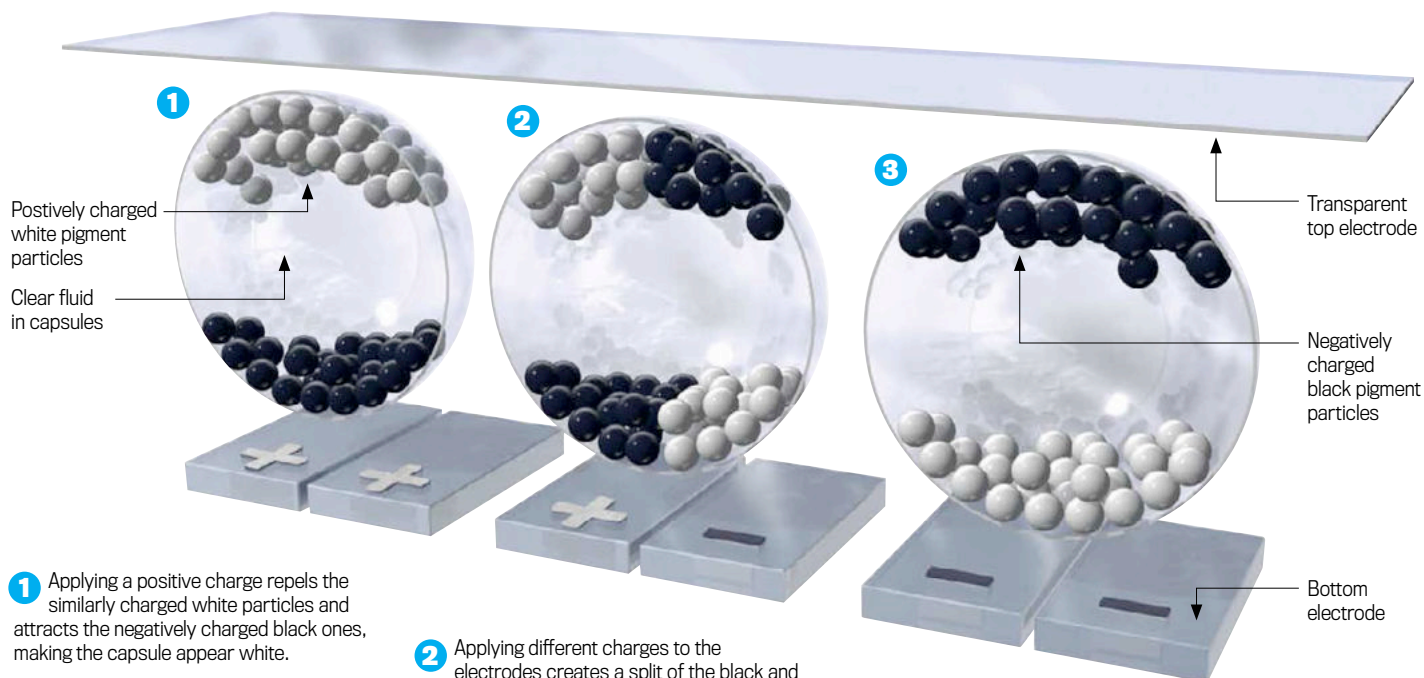


It might help if he looked where he was flying



HOW IT WORKS

COLOUR ELECTRONIC PAPER



1 Applying a positive charge repels the similarly charged white particles and attracts the negatively charged black ones, making the capsule appear white.

2 Applying different charges to the electrodes creates a split of the black and white particles, enabling the capsule to appear part black and part white for fine detail.

3 Flipping the polarity of the charge turns the capsule black. Although this takes less than a second, this switching process is currently too slow to enable video.

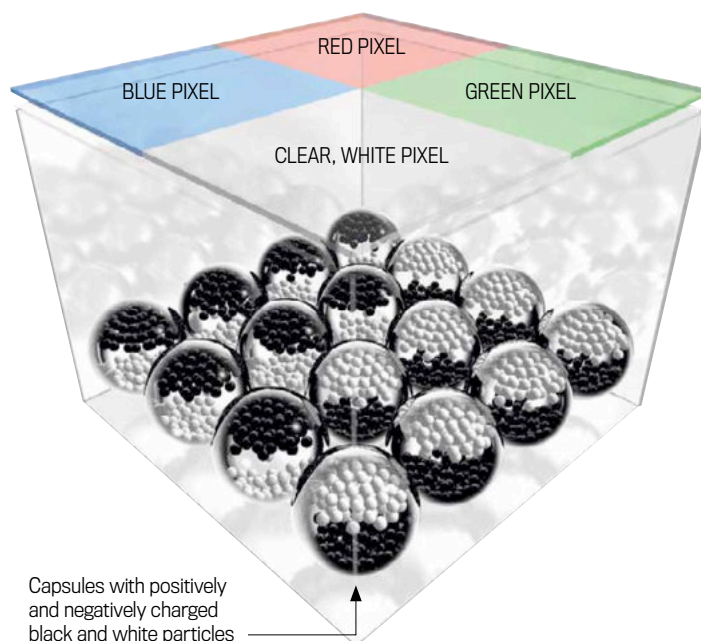
THERE'S LITTLE NOT to love about electronic paper. It requires no backlight, can be viewed in the brightest sunlight, and the only time it uses power is when the on-screen image is changed, which means that battery life is measured in weeks instead of hours. The trouble is that e-readers like the Kindle and Kobo are monochrome.

However, a number of companies are working on colour displays. One, by Liquavista, attempts to do this by manipulating coloured liquids with electric fields. Another by Xerox Fujifilm manipulates cyan, magenta and yellow particles within a clear liquid.

As promising as these approaches are, by far the most advanced effort comes from the

company E-Ink. Dubbed Triton (pictured, bottom left), this involves traditional monochrome pixels that reflect light. These are switched from black to white by adjusting the electric current passing through the screen, which alters the position of black and white pigment particles held in tiny capsules, as shown above. By placing a red, green and blue filter in front of the capsules, it creates subpixels that can make any colour except white. To create white, each pixel contains a region with no filter, allowing the monochrome display beneath to reflect light directly.

However, while this approach is straightforward, Triton's use of filters reduces the screen resolution by a factor of four. This is because what was previously the smallest visible unit (a monochrome pixel) becomes one of four blue, red, green or white sub-pixels.





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Q PAUL MCINTYRE, BY EMAIL

Could a black hole swallow an entire galaxy?

A THIS IS extremely unlikely. Although astronomers think that supermassive black holes exist at the cores



The Milky Way won't go down the plughole any time soon

of perhaps all galaxies, they are actually very small in comparison to the size of their hosts. This means that, while gravity is very strong near a black hole, their gravitational pull is comparatively weak far from the galactic core.

So although such black holes dominate the inner regions of galaxies, and often power extreme energy production, they don't have the strength to suck in entire galaxies. **AG**

Q RH GILLINGWATER, READING

Are compact fluorescent light bulbs safe?

A FLUORESCENT BULBS CONTAIN small amounts of mercury vapour. If you break one, the mercury level in the room can briefly exceed the safe threshold. But opening a window and putting the broken pieces in a sealed glass jar is enough to mitigate this risk. In areas with coal-fired power generation, fluorescent lights actually reduce the amount of mercury in



Fluorescent bulbs can reduce the level of mercury in the air

the air, because burning coal also releases mercury and fluorescent lights use less electricity, so they result in less coal being burned. **LV**

Did you know?

The largest swamp is in southwest Brazil. Called the Pantanal, it covers 15,000km², a greater surface area than England.



Q MARK RIDDLE, PLYMOUTH

How will continental drift change Earth in the future?



According to Prof Scotese, the Earth will look like this in 250 million years' time

A THE WORLD'S CONTINENTS may seem like 'terra firma', but in reality they're giant rafts of relatively light rock floating around the Earth's surface. Precision measurements using satellites have revealed that Europe and America are moving apart at around 30mm a year, while the Pacific is expanding four times faster still, making upheaval and changes in the appearance of our planet inevitable.

Geologists believe the result of this slo-mo action will be the formation of one gigantic supercontinent over

the next 250 million years. Such supercontinents are thought to have existed many times during the Earth's history, but their appearance depends on many factors, such as the speed and direction of the resulting collisions.

Using current measurements, Professor Chris Scotese of the University of Texas, Arlington, has carried out computer simulations that suggest Africa, Europe and the Americas will come together around the equator, trapping a huge expanse of sea between them. **RM**

Q MARTIN CHESTERMAN, LONDON

Is it better to get to sleep earlier?

A YES. YOUR BRAIN moves through different sleep states during the night. Rapid eye movement (REM) sleep is the shallowest, and then there are three progressively deeper non-REM sleep stages. You will normally cycle from REM to deeper sleep four or five times in a night, but the deepest sleep stage lasts much longer in the early part of the night. This is controlled by your personal daily cycle of the hormone melatonin,



'One hour before 11 is worth two after 7' is good advice

not the time that you go to bed. After about 3am, the brain skips the deepest sleep stage altogether. And lying in late only gives you more REM sleep, which is less restful. **LV**

THE NIGHT SKY: WHAT CAN I SEE IN JANUARY?

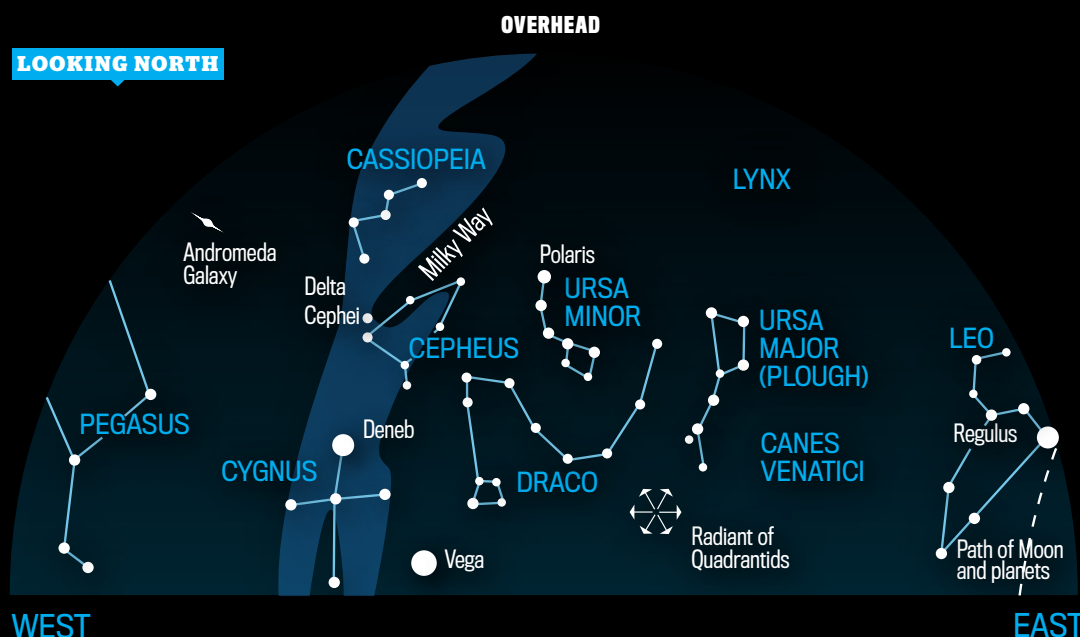
BBC
ONEDon't miss *The Sky At Night* on BBC One every month
www.bbc.co.uk/skyatnight

Astronomy with
Heather Couper
and Nigel Henbest



IF THERE'S EVER a month for glitterati stars, this is it. Dazzling Orion and scintillating Sirius parade down the red carpet of the heavens, joined by the awesome planet Jupiter high in the southern skies. Yes – it's cold outside, but this is the best time of year to find your way around the firmament, with brilliant constellations writ large. Ironically, the chilliest days of the year find Earth at its closest point to the Sun; it's at perihelion on 2 January at 00:59am, but our North Pole points away from the warmth of our local star at this time of year.

LOOKING NORTH



LOOKING NORTH

3-4 January, evening

The Quadrantid Meteor Shower peaks tonight. The shooting stars – debris deposited by the comet 2003 EH1 – streak into our atmosphere around 100km up. The display is usually brief and intense, but this year, the Moon – which rises at 10pm – will spoil the show.

All month, all night

Cepheus – a triangular constellation – hosts a gem. It's the star Delta Cephei, which varies in luminosity over five days. The star lends its name to a host of stars called Cepheid variables. The longer the variability, the bigger and brighter the star. Cepheids are cosmic beacons, enabling astronomers to measure the scale of space.

LOOKING SOUTH

All month, all night

The spectacular constellation of Orion is riding high in the south. Look below the three stars of his 'belt' for the Orion Nebula – a 'star factory' busy forming infant stars. It's a fantastic sight through binoculars or a telescope.

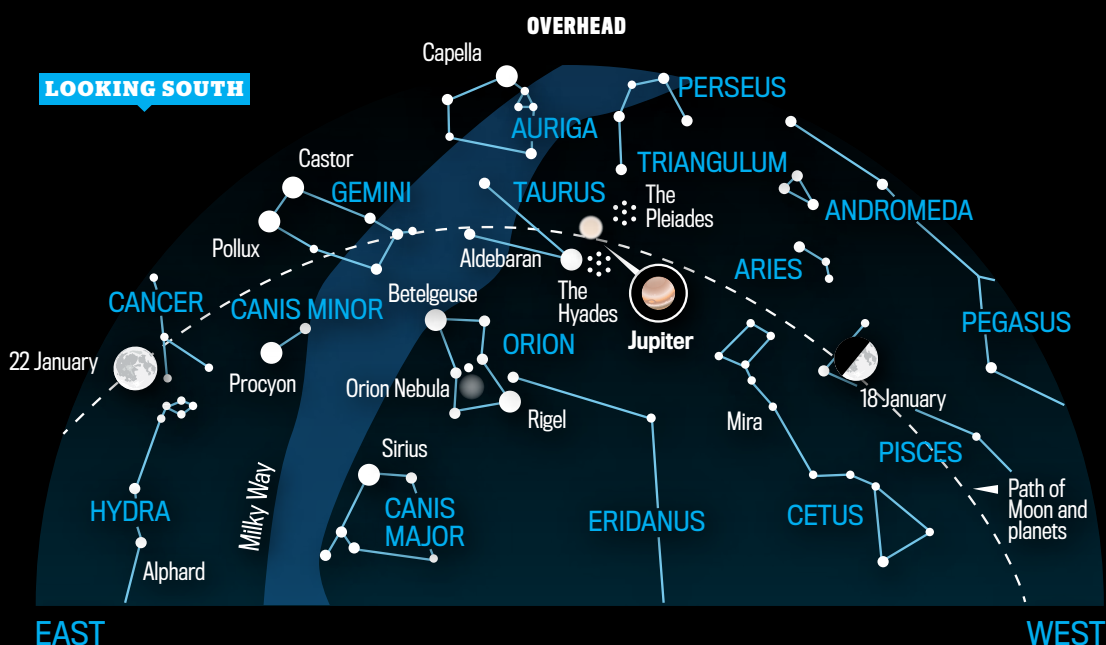
All month, all night

Sirius – the brightest star in the sky – is strutting his stuff. The 'Dog Star' isn't actually all that bright, but happens to be nearby – only 8.6 light-years away. Through a telescope, you can spot his small companion – a collapsed white dwarf star nicknamed 'the Pup'.

21-22 January, all night

The Moon makes a beautiful group with the planet Jupiter and the red giant star Aldebaran. With binoculars, you'll be able to see the surrounding Hyades star cluster.

LOOKING SOUTH



Find out more

Sky At Night Magazine

On sale now, priced £4.75

Q ADAM DOOLEY, MANCHESTER

What colour is the Martian sky?

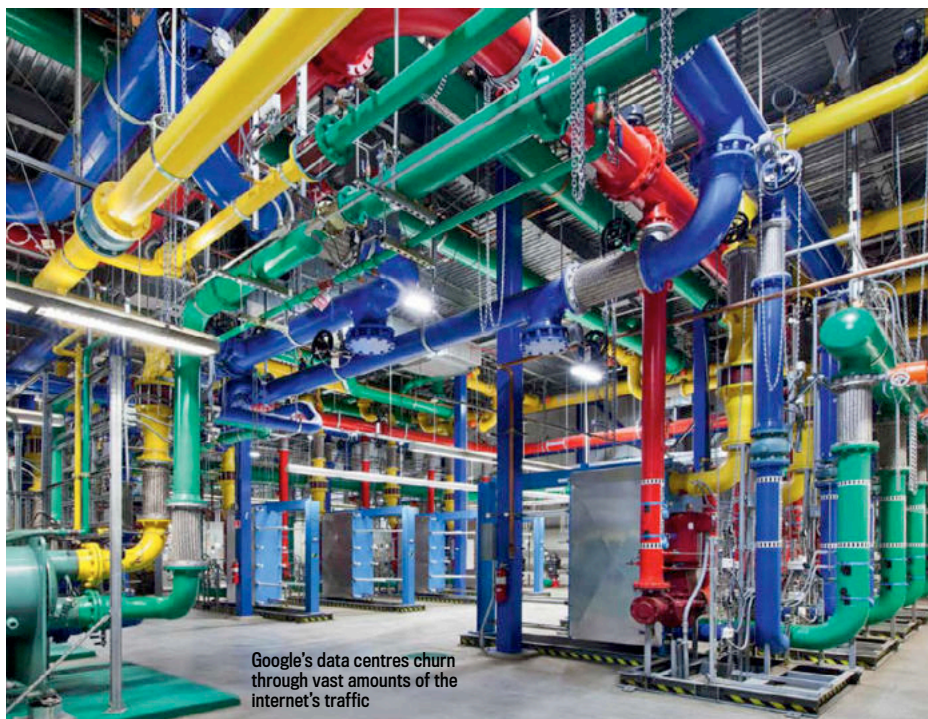
A ON EARTH, THE sky appears blue because atmospheric molecules scatter blue light more than other wavelengths. If the Martian atmosphere were clear like Earth's, the Martian sky would also appear blue or indigo – though it would be deeper in colour than Earth's, due to Mars's much thinner atmosphere.

But Mars's atmosphere contains a permanent haze of dust particles composed mainly of iron oxides such as limonite and magnetite, the same minerals that give the planet's surface its characteristic red colour. This haze



Mars's sky is a ruddy brown, as this image from NASA's Curiosity rover reveals

preferentially absorbs blue light and results in a yellow-brown sky, often described as 'butterscotch'. At sunset and sunrise the sky can appear pinkish-red because there is more absorption of blue light due to the increasing thickness of atmosphere through which sunlight is travelling. **AG**



Google's data centres churn through vast amounts of the internet's traffic

Q KUSHIL GANATRA, MIDDLESEX

How many terabytes of data are on the internet?

A ONE WAY TO answer this question is to consider the sum total of data held by all the big online storage and service companies like Google, Amazon, Microsoft and Facebook. Estimates are that the big four store at least 1,200 petabytes between

them. That is 1.2 million terabytes (one terabyte is 1,000 gigabytes). And that figure excludes other big providers like Dropbox, Barracuda and SugarSync, to say nothing of massive servers in industry and academia. **GM**

Did you know?

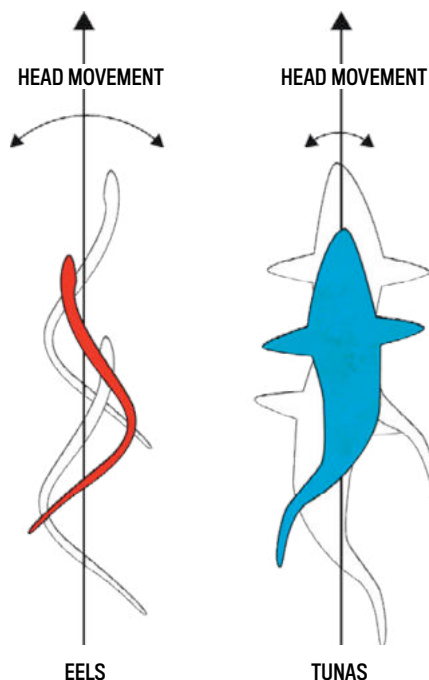
The Mariana Trench in the Pacific Ocean is the deepest natural point on Earth at 11km (6.8 miles) below sea level.



Q SAM HALL, BY EMAIL

How do eels swim?

A MOST FISH SWIM by generating a side-to-side wave that moves backwards along the body. The wave gets larger as it moves backwards but it stays symmetrical, so the sideways forces cancel out and the net thrust pushes the fish forwards. There is a trade-off between speed and manoeuvrability: a stiffer body is faster because most of the sideways flexing is at the tail end, where it generates the most thrust. But the less you flex, the slower you turn. Eels are at the low speed/high manoeuvrability end of this spectrum, with a wave that has virtually the same amplitude all the way along the body. **LV**



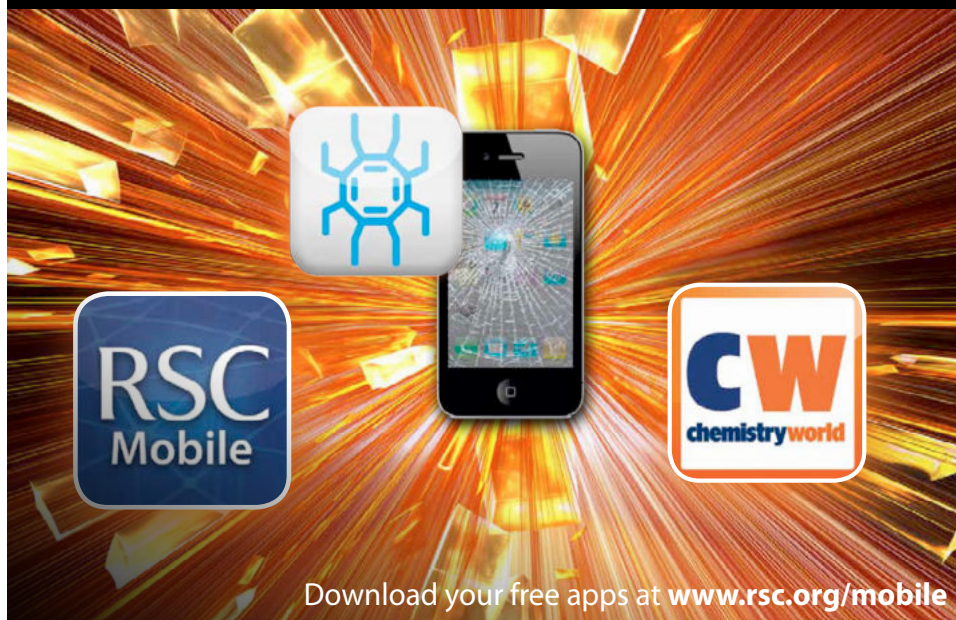
With more movement along the entire body, an eel moves much slower than a tuna

NEXT MONTH Over 20 more of your questions answered



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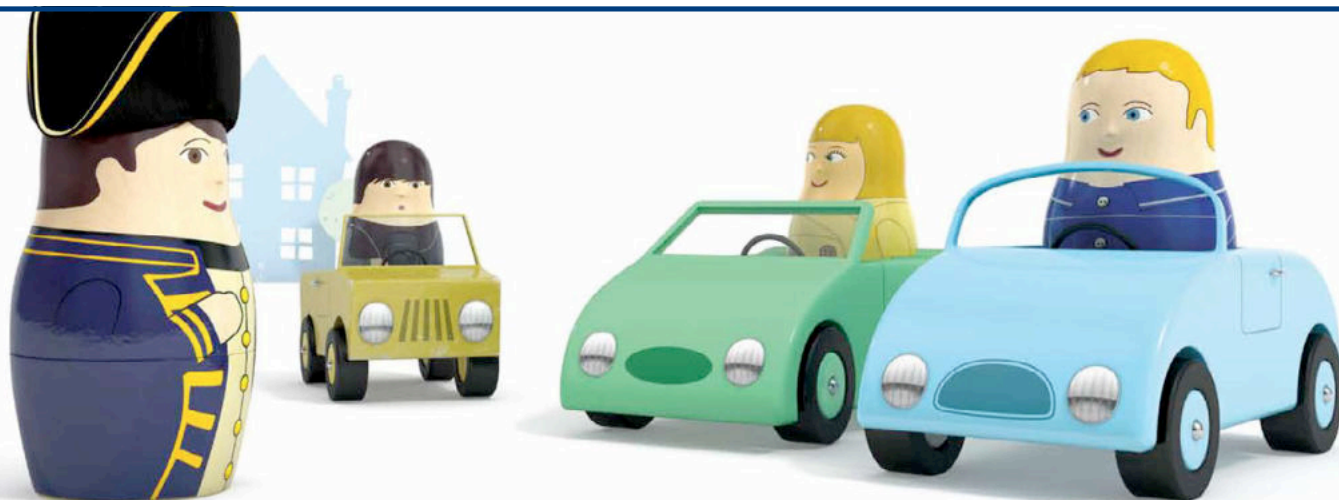


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HOW DO WE KNOW?

WHAT KILLED THE DINOSAURS?

BY DAVID NORMAN

The amazing story of how we've come to learn the fate of our reptilian predecessors

THEY CAME. THEY ruled. They died. Considering that the end of the dinosaurs took place millions of years ago, it is remarkable how much we've learnt about their demise. To appreciate where our knowledge has come from, we need to delve into the fascinating history of palaeontology – the study of fossils.

Fossils have been known about for centuries, but it was not until French naturalist Georges Cuvier (later Baron Cuvier) began to take an interest in them in the 18th Century that their significance was fully understood.

In 1796 Cuvier published detailed descriptions of fossil elephant remains (those of mammoths and the American mastodon), which he compared with the bones and teeth of living elephants. He revealed that some fossils belonged to animals that were no longer alive: they were *extinct*. At the end of the paper, he wrote: "All of these facts, consistent among themselves, and not opposed by any report, seem to me to prove the existence of a world previous to ours, destroyed by some kind of catastrophe."

Over the following years, Cuvier developed his 'catastrophist' interpretation of the history of Earth. He studied the geology of the Paris

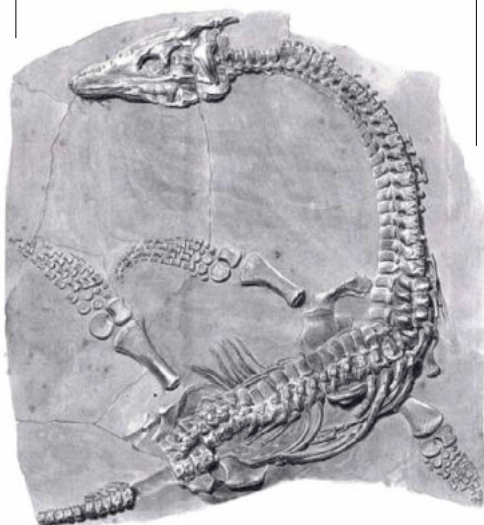
Basin and saw that it comprised a succession of sedimentary layers. Each layer contained its own recognisable fossils (its fauna), but Cuvier noticed that each fauna was replaced abruptly following a catastrophe, such as being submerged by floodwater.

He also described a variety of newly discovered and strange fossil reptiles, including pterosaurs (winged reptiles) and mosasaurs (gigantic marine lizards) and this led him to speculate

about an 'Age of Reptiles', a time when reptiles dominated Earth, rather than the mammals that do so today.

Cuvier's insights inspired a new era of fossil hunting. Over the first three decades of the 19th Century, several English collectors and geologists made some spectacular discoveries. Mary Anning from Lyme Regis in Dorset discovered ichthyosaurs (dolphin-shaped giant swimming reptiles), plesiosaurs (large, turtle-flipped and long-necked, swimming reptiles) and the partial skeleton of a pterosaur. William Buckland, an English theologian and geologist, described the teeth and bones of a giant, carnivorous, land-living reptile (*Megalosaurus*) collected from a quarry at Stonesfield in Oxfordshire. And Gideon Mantell, a general practitioner and amateur geologist from Lewes in West Sussex, discovered the fossilised teeth of a giant herbivorous reptile. After consulting Cuvier, Mantell named these fossils *Iguanodon*.

This new fossil evidence proved Cuvier's hunch correct. There was a time in Earth's history (referred to then as the 'Secondary Era' – now it is the Mesozoic Era) when the world was largely populated by gigantic land and sea-going reptiles. These remarkable new discoveries



A fossilised plesiosaur discovered by Mary Anning at Lyme Regis, now held in the Natural History Museum





How do we know?

> IN A NUTSHELL

Find out about the very first discoveries that hinted at a lost world of 'terrible lizards', and the investigations that led to the discovery of how dinosaurs became extinct. The fascinating story of palaeontology has enabled our understanding of one of the most dramatic events in the history of life: the end of the dinosaurs.

Ever since fossil discoveries in the late 18th Century, we've wondered how a world of giant reptiles came to an end

→ provoked very wide interest both scientifically and publicly. New fossils were bought privately from collectors in order to be added to gentlemen's 'cabinets of curiosities' or donated to museums.

In Britain at this time a young, ambitious, medically-trained scientist called Richard Owen became keenly interested in Cuvier's work. In the mid-1830s Owen travelled the country to study and review as many collections of fossil reptiles as he could. In 1840 and 1842 he published detailed reports through the newly

founded British Association for the Advancement of Science (BAAS).

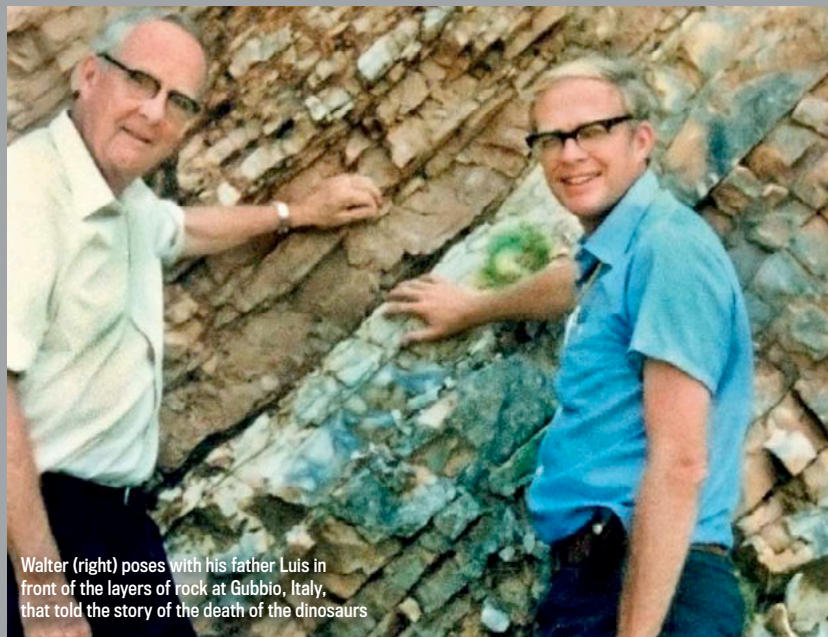
The second of Owen's reports is particularly famous because it was here that he coined the term 'Dinosaur'. In what was at the time a masterpiece of rational argument and anatomical insight, he drew on Cuvier's intuitions and demonstrated that during the 'Secondary Era' there were some remarkable extinct animals that represented the zenith of reptilian organisation. These were the enaliosaurs (gigantic reptiles of the oceans that filled the ecological

niches occupied today by whales and dolphins), the pterosaurs (reptilian equivalents of birds and bats today) and the dinosaurs (huge land-living animals that corresponded to the elephants, rhinos and hippos).

While the first half of the 19th century was dominated, intellectually, by Cuvier and his 'catastrophist' thinking, the latter half was marked by the 'uniformitarianism' advocated by the geologist Charles Lyell and the strongly allied theory of evolution by Natural Selection proposed by Charles Darwin. Lyell and Darwin took a non-catastrophic view of Earth's history: disasters did occur and extinctions were indisputable; however, this did not greatly affect the gradual (uniformitarian) process of change that could be traced in the rock and the fossil record.

THE KEY OBSERVATION

A father and son team came up with startling evidence for a mass-extinction event



Walter (right) poses with his father Luis in front of the layers of rock at Gubbio, Italy, that told the story of the death of the dinosaurs

In 1977 Walter Alvarez examined a geological sample collected near the town of Gubbio in Italy. The sample was interesting because it crossed the boundary between the Cretaceous and Palaeogene periods (65 million years ago). It comprised a 2cm band of barren grey clay sandwiched between a section of white limestone that contained late Cretaceous planktonic fossils, and a layer of reddish sandstone that contained the remains of early Palaeogene planktonic fossils. Walter Alvarez wanted to know how long it had taken for the clay layer to form between the two limestones. His father Luis, a Nobel Prize winning astrophysicist, suggested this might be possible by measuring the quantity of

micrometeorite dust recorded in the clay layer, as such dust falls to Earth at a constant and predictable rate. Measuring the clay's iridium concentration was one technique that was available, as iridium is an element that is derived from meteorite debris.

Walter and Luis Alvarez discovered extraordinarily high levels of iridium in the clay, far in excess of what would have possibly accumulated even in many millions of years. This observation led them to theorise that a large asteroid impact, which would have vaporised the iridium-enriched asteroid material, created an enormous dust cloud that eventually settled and left its signature in that remarkable clay layer.

EXTINCTION EVENTS

However, by the 20th Century, the roster of fossil discoveries had expanded considerably, alongside improvements in the methods for measuring time using rock samples. With this increasing data it became obvious that Cuvier's catastrophes were real and not the by-product of missing data as Lyell and Darwin had suggested. Various explanations concerning these major punctuations in the history of life were bandied around. These included biblical views, such as the idea that extinction events were pre-ordained.

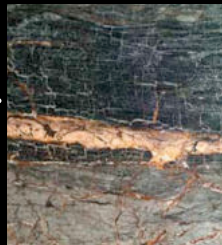
Palaeontologists began to speculate about mass extinctions more openly. Given the controversy that surrounded Darwinism at this time, some adopted a range of non-Darwinian models to explain extinction events.

Racial senility was one such concept. This saw life as a ladder-like succession of types, each new form better than the last. Dinosaurs, for example, represented a Mesozoic form of reptilian life that was replaced in younger rocks by 'superior' types of animal such as mammals. This view was supported by the observation that the anatomy of dinosaurs became increasingly 'bizarre' through time, manifested by the development of outlandish spines, horns and frills, as well as the loss of teeth, suggesting that the race had become old and, in effect 'senile'.

Another palaeontologist Baron Franz Nopcsa added a twist to this idea by suggesting that such abnormal growths represented malfunctions

TIMELINE

Scientists have spent over 200 hundred years trying to understand what killed the dinosaurs

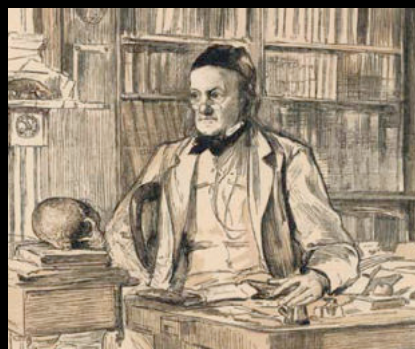
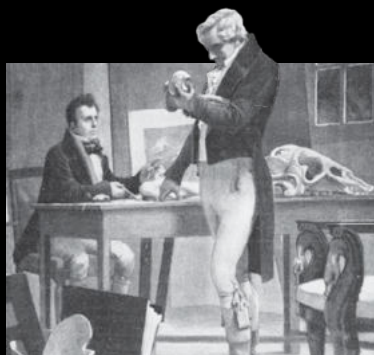


Giovanni Arduino recognised that Earth's rocks could be divided into three types: Primary, Secondary and Tertiary. The intervals between these types marked significant mass-extinction events.

1750

1796

Georges Cuvier compared fossil elephant remains with the bones and teeth of living elephants, demonstrating for the first time that some fossils belong to animals that are no longer alive today.



Richard Owen coined the name 'dinosaur' and demonstrated that during the 'Secondary' (Mesozoic) Era there were some truly remarkable extinct animal types that he claimed represented the zenith of reptilian organisation.

1842

1980



The discovery of the **Chicxulub Crater** dated at the K-Pg boundary, on the Yucatán Peninsula of Mexico provides the 'smoking gun' for the Alvarez theory.

Luis and Walter Alvarez proposed that an asteroid was responsible for the K-Pg mass-extinction event after discovering high levels of the element iridium in a layer of clay dating back 65 million years.

1981



Dewey McLean, Vincent Courtillot and Gerta Keller develop the Deccan volcanism theory of dinosaur extinction. Massive volcanic eruptions flooded Earth's surface with greenhouse gases.

1991



had occurred near our Solar System at that time, but the chemical signature from such an event (plutonium-244) was absent from the samples. Eventually, the father and son concluded that a large asteroid impact, which would have vaporised the iridium-enriched asteroid material, caused the anomaly.

DEEP IMPACT

By 1980 a fully fledged theory was launched upon the world by Luis and Walter Alvarez and their colleagues. In summary, an incoming asteroid about 10km in diameter punched a hole in the atmosphere and the Earth's crust. The energy released, equivalent to hundreds of millions of tonnes of TNT, and matter ejected as the asteroid vaporised, created an enormous dust cloud that led to the K-Pg mass extinction event and death of the dinosaurs. This entirely new hypothesis was met by skepticism from the palaeontological community.

But, as time elapsed, more iridium anomaly sites were discovered around the world, supporting the Alvarez theory. In addition, impact-related structures such as very thick debris beds (created by tsunamis and debris flows), microscopic spherules (glassy droplets of silica sprayed out from the impact site) and 'shocked' quartz grains all lent additional support to the suggestion of a high-energy impact. Furthermore, the relative thickness and density of ejected material in these different geographic locations began to imply a trajectory for the incoming asteroid, as well as hinting at a general location in Central America as the likely impact site.

In 1991 the discovery of the 180 to 200km-wide ring-shaped Chicxulub Crater in Mexico crowned the Alvarez theory. Since the asteroid had impacted the continental shelf, this would have released vast quantities of climatically sensitive gases from the carbonate and sulphate-rich layers bound up in the shelf sediments with disastrous effects: extended darkness, global cooling and acid rain.

Despite increasingly strong support for the asteroid theory, there is another extinction theory that must be considered. This focuses on the three massive volcanic eruptions that led to the formation of the Deccan Traps in western India. The Traps, multiple layers of solidified basalt, cover an area

NEED TO KNOW

Key terms to understand how the dinosaurs were wiped out

1 Asteroid

A small rocky or metallic body in orbit around the Sun. Most occur in the asteroid belt between the orbits of Mars and Jupiter, although other families exist, such as the near-Earth asteroids which pose a collision danger with Earth.

2 Deccan Traps

One of the largest volcanic features on Earth formed 60–68 million years ago. They consist of multiple layers of solidified lava that are more than 2km thick and cover an area of 500,000km² in west-central India.

3 Iridium

An element derived from micrometeorite dust that falls to Earth at a constant and predictable rate. It is found in much higher levels in asteroids than on the surface of Earth.

4 K-Pg extinction

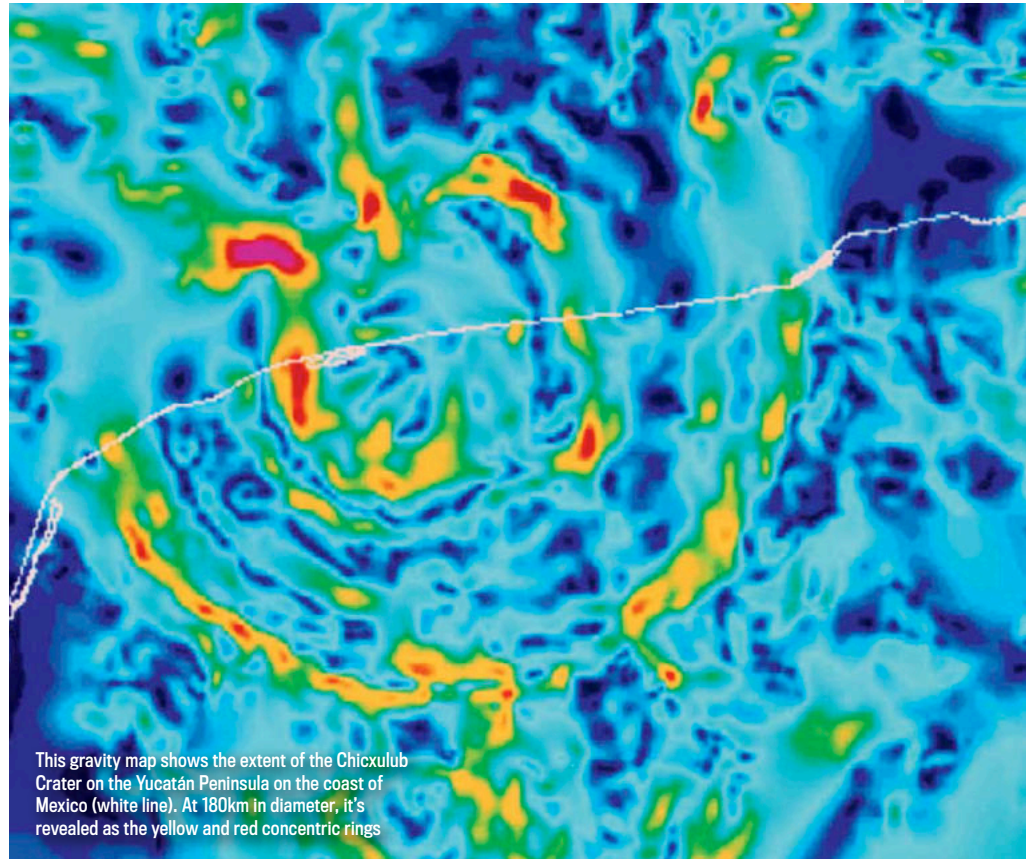
The Cretaceous–Palaeogene extinction event, also known as the Cretaceous–Tertiary (K–T) extinction event, occurred approximately 65.5 million years ago. It was a large-scale mass extinction of animal and plant species in a geologically short period of time.

5 Palaeontology

The study of prehistoric life through fossils. Palaeontological observations date back to the 5th Century, but the science became established in the 18th Century as a result of Georges Cuvier's work on comparative anatomy, and developed rapidly in the 19th Century.

that is currently larger than the size of France (and may have been up to three times as large in the past). The massive outpouring of volcanic material occurred during a narrow interval of time across the K–Pg boundary.

Speculations about a link between the Deccan Traps and the dinosaur extinction began in the early 1970s. However, it was not until 1981 that Vincent Courtillot, Gerta Keller and



This gravity map shows the extent of the Chicxulub Crater on the Yucatán Peninsula on the coast of Mexico (white line). At 180km in diameter, it's revealed as the yellow and red concentric rings

other proponents of the volcanism model began to gather data. Early modelling focused on the gases released by the huge volcanic eruptions and how this might have led to a sudden cooling of Earth and mass extinction.

The dispute with the asteroid theorists tends to focus on whether the impact signatures (iridium anomaly, microspherules, 'shocked' particles) were necessarily of extraterrestrial origin, or whether they may equally well have been formed during phases of explosive volcanism.

In terms of the data available, the asteroid theory appears to be the more robust. The flood-volcanism theory does not adequately explain the impact signature. Courtillot and Keller now seem to accept that an asteroid impact (or indeed several) occurred, but claim that these were merely a contributing factor to the extinction event.

We know that the K–Pg event caused the death of around 75 per cent of Earth's life, most notably all the non-avian dinosaurs, a range of marine reptiles (ichthyosaurs, plesiosaurs and mosasaurs) and the pterosaurs (flying reptiles). But what is equally interesting is that other groups survived relatively unscathed:

the avian dinosaurs (birds), as well as the mammals, lizards, snakes, tortoises, crocodiles, a huge variety of fish and countless others.

Both the asteroid and the flood-volcanism theory describe the rapid disturbance of the environment on a global scale. In both scenarios, this could have caused the extinction of many lifeforms. However, given the evidence, the asteroid impact theory would be the safest bet as to why our reptilian predecessors were wiped out. ■

Dr David Norman is a palaeontologist at Cambridge University and the author of *Dinosaurs: A Very Short Introduction* (OUP)

Find out more



4 Extinct!

Adam Rutherford explores why almost all life on Earth became extinct around 250 million years ago.
www.bbc.co.uk/programmes/b01hjs0s

In Our Time

In this 2005 episode, Melvyn Bragg and guests discuss the extinction event.
www.bbc.co.uk/programmes/p003k9d0

FOCUS

SCIENCE AND TECHNOLOGY
FEBRUARY ISSUE

WONDERS OF LIFE

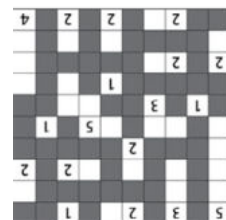
THE SCIENCE BEHIND BRIAN COX'S EPIC
NEW BBC SERIES

ON SALE 10 JANUARY 2013

PHOTO: REX

COMPETITION TERMS AND CONDITIONS:

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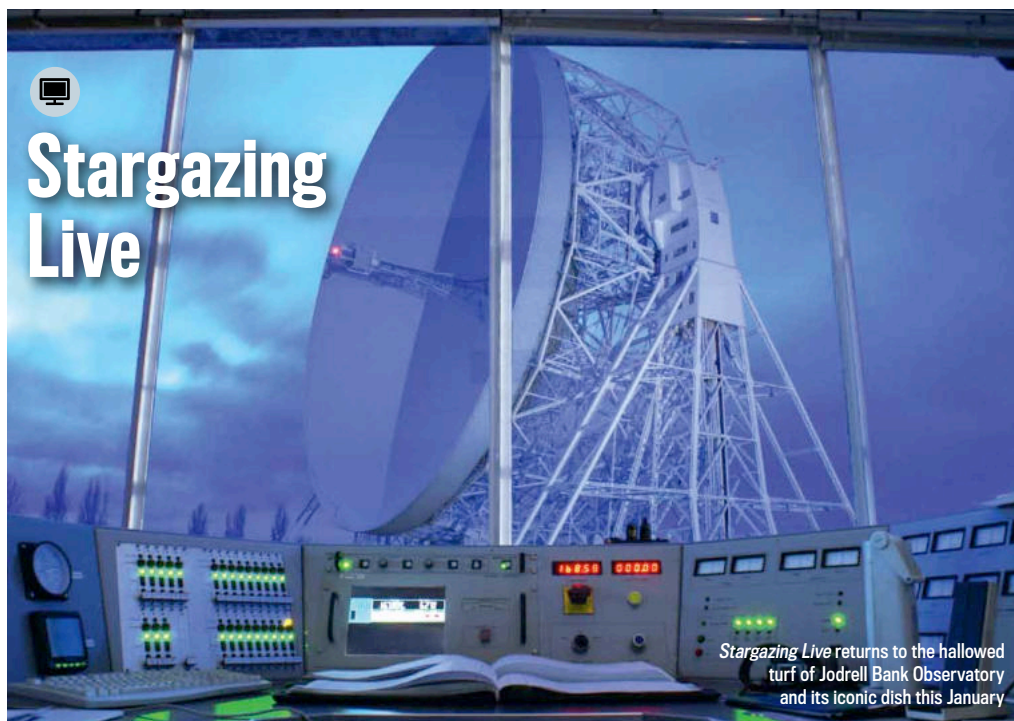
MINDGAMES PUZZLE
SOLUTION
Stop cheating! Don't look at
this until you've attempted
the puzzle on p111.

TO DO LIST

PLAN YOUR MONTH AHEAD WITH OUR EXPERT GUIDE

-  VISIT
-  WATCH
-  LISTEN
-  TOUCH
-  PLAY
-  READ

PICK OF THE MONTH



Stargazing Live

Stargazing Live returns to the hallowed turf of Jodrell Bank Observatory and its iconic dish this January

→ COME JANUARY YOU'RE skint, you've overeaten, and spring is a long way off. But at least you have *Stargazing Live* to look forward to. Presenters Brian Cox, Dara O Briain, Liz Bonnin and Mark Thompson return with the show that mixes studio action with a live audience with filmed footage and live links to far-off locations.

As well as catching the odd shooting star from the Quadrantids Meteor Shower, which returns every January, *Stargazing Live* will also be looking at comets and asteroids. Since the Sun's also having an active phase, you can join the team in trying to spot the Northern Lights, and learn how our local star excites Earth's magnetic field to create the spectacular displays.

They'll also be recreating one of the most important telescopes in history: the 20ft instrument through which brother and sister team William and Caroline Herschel observed planets and comets.

Part of the this year's programme will come from NASA's Jet Propulsion Lab (JPL), nerve centre for the Curiosity rover, so we can hope for some updates from the Red Planet. Either way, NASA's Curiosity mission will be the starting point for finding out about how they go looking for life beyond Earth, why signs of past or present water are so important, and whether or not we could terraform Mars to be habitable like Earth.

And if you liked *Stargazing Live* last year, there's even more to look forward to this time around. Taking a leaf out of *Springwatch*'s book, the regular show will be followed at 9pm by *Back To Earth*, a half hour of chat with experts and celebrity guests.

TIMANDRA HARKNESS



Stargazing Live airs at 8pm on 8, 9 and 10 January on BBC Two

DON'T MISS!



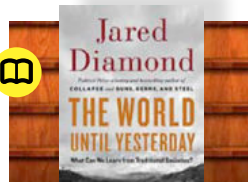
Walking With Dinosaurs

A herd of dinosaurs take the floor in this live show of the BBC programme. Yes, there is a to-scale T-rex. **p98**



Pyramids 3D

Explore the Great Pyramids of Giza without actually being there. Take a 3D tour on your iPad with expert guides. **p102**



The World Until Yesterday

In his new book, Jared Diamond looks at what we can learn from our hunter-gatherer past. **p104**



VISIT

EVENTS & EXHIBITIONS

WITH JHENI OSMAN

FROM 23 NOV

Dr Livingstone, I Presume?

National Museum of Scotland, Edinburgh, free, until 7 April, www.nms.ac.uk



AS THE FIRST European to cross Africa, David Livingstone is something of a Scottish national treasure. To celebrate 200 years since his birth, this exhibition pieces together his early home life in Blantyre, his study of medicine and his efforts to abolish the slave trade, telling the story through Livingstone's personal possessions and the museum's African collections.

28 NOV-30 MAY

Romantic Chemistry

Royal Society, London, free, royalsociety.org



JUST AS BRIAN Cox has become the poster boy for science today, in the early 19th century young scientists like Sir Humphry Davy were idolised by the fashionable crowd in London and Paris. In this exhibition, archive materials and manuscripts reveal how chemical research and the discovery of new elements, at the turn of the 19th century, led to chemistry becoming cool and Davy and his chums acquiring celebrity status.

14 DEC-7 FEB

Chasing Ice

In cinemas from 14 December, for venues and dates see <http://chasingice.co.uk>



TO DEMONSTRATE THE rate at which the planet is losing its icebergs, photographer James Balog set out across the Arctic and set up cameras to record the melt over three years. This film records his journey, together with a team of adventurers, across the ever-changing landscape. Using time-lapse photography, the film shrinks the camera footage into seconds, showing how monolithic chunks of ice are disappearing at an unprecedented speed.

JHENI OSMAN is a science writer and the author of *100 Ideas That Changed The World* (BBC Books, £9.99)



EDITOR'S CHOICE

Enjoy a scene that hasn't been witnessed on Earth for millions of years

FROM 26 DEC

Walking With Dinosaurs: The Arena Spectacular

Venues across the UK, until 26 May, prices vary, dinosaurlive.com



IF WE'VE LEARNED anything from the *Jurassic Park* movies, it's that bringing giant, toothy reptiles back to life rarely ends well. Despite this, scientists are still trying to resurrect lost species, starting with the woolly mammoth. And they're making headway too, after recently discovering a remarkably well-preserved specimen buried in the Siberian permafrost. But with dinosaurs having lived 65 million years ago, instead of a mere 10,000, finding some viable dino DNA to copy any time soon looks extremely unlikely.

In the meantime, the next best thing is the lifelike spectacle that is *Walking With Dinosaurs*. Based on the

award-winning BBC television series of the same name, the show returns to UK shores, revealing the key to the prehistoric beasts' incredible 200-million-year domination. Spanning the Cretaceous, Jurassic and Triassic periods, the show follows dinosaurs as they battle it out for survival.

Since its inception almost 13 years ago, the production has been brought right up to date. The herd of 20 to-scale dinosaurs looks more realistic than ever before, from their skin texture to their beady eyes. And you would hope so, considering the entire show cost a dizzying £10,000,000 to put together! It's a true technological masterpiece that will wow the whole family.

FROM 5 JAN

Good Vibrations

At-Bristol, every weekend until 27 Jan, free with general entry, www.at-bristol.org.uk



SOUND PASSES THROUGH compressible substances such as air and water as waves of pressure. This live family show uses demonstrations and music to reveal exactly what sound is and how it's made. Play some unique instruments, watch dancing flames and explore the invisible world of sound. It's a great way to keep the kids quiet for an afternoon – as long as you don't mind a whole lot of other noise!

8 JAN-12 FEB

Further Astronomy

Royal Observatory Greenwich, London, Tuesdays 7pm-9pm, £72, www.rmg.co.uk

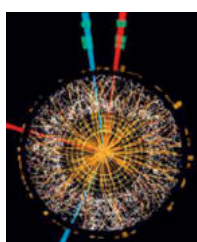


DISCOVER THE SECRETS of the Universe in a six-week course aimed at those with some prior knowledge of astronomy. Travel the Solar System from the Moon to the comets of the Oort cloud, explore the Milky Way and the black hole at its heart, delve into the mystery of dark energy, and look into the future when our Galaxy will collide with the spiral galaxy Andromeda.

15 JANUARY

The Particle At The End Of The Universe

Royal Institution, London, 7pm-8.30pm, £10 adults, £7 concessions, members free, www.rigb.org



AFTER £5.6 BILLION, decades of effort, and the work of over 6,000 researchers at the Large Hadron Collider, the Higgs boson has finally turned up. In this talk, Caltech physicist Sean Carroll discloses the stories of the scientists who devoted their lives to discover the elusive particle – and reveals the horse-trading and skulduggery that sometimes went on behind the scenes.

16 JANUARY

The Psychology Of A Volcano

Natural History Museum, London, 2.30pm, free, www.nhm.ac.uk/nature-live



MEET A SCIENTIST who analyses rocks for a living. Sound dull? Well, these are no ordinary stones from the back garden. They are specimens taken from eruptions in order to discover how volcanoes have behaved in the past. From these rocks, scientists can also predict how a volcano will act in the future.

SPEAKER OF THE MONTH

22 JANUARY

Adrian Bird

Royal Society, London, 6.30pm-7.30pm, free, royalsociety.org



Who is he?

CBE, FMedSci, FRS... Prof Adrian Bird has a lot of letters after his name. At the University of Edinburgh, he heads up an eponymous lab where his team look at how our genetic make-up affects our health.

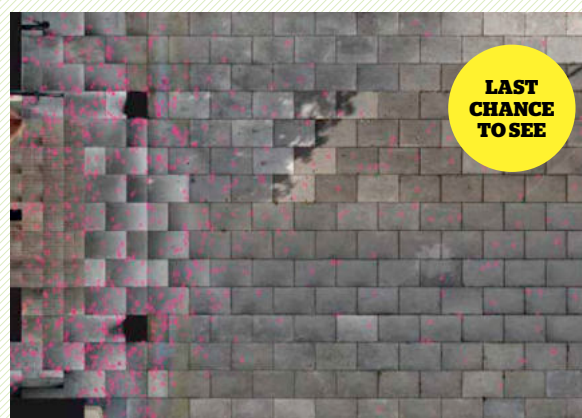
What is he talking about?

The human genome was sequenced over a decade ago, but we're still unsure how to use this information to treat patients. Prof Bird explains the research that's being done to bridge this gap. He reveals, for instance, how errors in one simple DNA sequence, just two base pairs long, are implicated in an array of diseases, including some forms of autism. A better understanding of our genes could eventually lead to better diagnoses and treatments.

UNTIL 5 JAN

Digital Aesthetic³ Exhibition

Harris Museum & Art Gallery, Preston, free, digitalaesthetic.org.uk


LAST CHANCE TO SEE


EXPLORING THE IMPACT of digital technology on our sense of self, this exhibition will get the grey cells thinking about how our perception of reality is shaped by the digital world. On display are a variety of ways in which artists use technologies such as video, 3D and touch panel installations. From an artwork exploring death to one trying to teach Japanese, if you enjoy the merging of science and art this exhibition is one to catch before it ends in January.



WATCH

TV, DVD, BLU-RAY & ONLINE
WITH TIMANDRA HARKNESS

DECEMBER

The Modern Alchemist: RI Christmas Lectures

BBC Four, after Christmas



SINCE 1825, THE Royal Institution has entertained and intrigued audiences with its Christmas Lectures, and this year it's chemist Dr Peter Wothers (pictured) who gets his turn in the famous lecture theatre. He'll be bringing us right up to date with the electrical chemistry of our brains, the subatomic engineering of materials and of course lots of fire and explosions. See p44 for our exclusive interview with the man himself.

FROM 20 DEC

The Zoo Christmas Special

Animal Planet, 20 December, 8pm

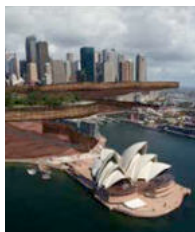


NOBODY CAN SPEND an entire year watching serious science and impressive engineering. So why not take an hour out to watch Dublin Zoo in the snow? Grey wolves, snowy owls and snow leopards are happy with the wintry weather, but the zookeepers have to keep the other residents happy in record low temperatures. And in between wrapping up reptiles and insulating insects, it's time to get festive, as the human visitors enjoy the Christmas spirit.

JANUARY

Strip The City

Discovery, January



DUBAI, LONDON, SYDNEY and San Francisco face very different natural challenges, but all of them hide secrets. This six-part series uses CGI to strip off layers of concrete, soil and water, revealing the ingenious engineering that keeps skyscrapers standing, water flowing and transport running in six great cities. But just as gripping to watch are the humans who make it all happen, working below ground or high above the streets to enable millions of citizens to live, travel and work.

TIMANDRA HARKNESS is a BBC Radio 4 presenter and stand-up comic. Her latest show is 'Humans Vs Nature: Engineering FTW'

EDITOR'S
CHOICE



Liz Bonnin hunts for relics in the Science Museum's Swindon hangar

7 JANUARY

Horizon

BBC Two, from 7 January

THE BBC'S FLAGSHIP science series returns for a new season. And if you're wondering why you had to eat so many sweets and snacks over the festive period, you'll enjoy the episode on taste and why we're driven towards fat and sugar. But some of the programmes tackle deeper questions about human life.

Bang Goes The Theory's Liz Bonnin, freshly returned from filming *Stargazing Live* at NASA's Jet Propulsion Laboratory, visits an even more exotic location: Swindon. That's where the Science Museum keeps things like aeroplanes, railway engines and printing presses in its enormous storage site on a former airfield. It's like a giant filing cabinet of the age of invention. Liz will be asking: what makes some countries and periods of history so prolific when it comes to innovation?

In another episode, space-loving Dr Kevin Fong tries to find out why humans are fallible and whether we can prevent deadly slip-ups. Everyone makes mistakes, but some people's matter more than others: airline pilots, for example, or surgeons. By understanding what leads us astray, can we reduce human error? Or can medicine use some of the tools that make aviation so safe, like simple checklists?

But imperfect as we are, humans are creative in all sorts of ways, from solving problems to producing works of art. And the first episode of *Horizon* asks what neuroscience can tell us about the creative process. It's hoped that by finding out what the brain is up to, we can enhance our creativity and find out more about the mind, including the relationship between creativity and madness.

FROM 08 JAN

Taboo

National Geographic, starts 8 January, 9pm



EVER WONDERED IF you're normal? This series should reassure you that there's a wide range of human behaviour. Meet the London collector of shrunken heads, the body piercing world record holder (over 8,000 since you ask) and the couple whose dogs also get a wedding ceremony. Extreme body modification, naturist weddings – and that's before we've even mentioned unorthodox sexual preferences. You feel boringly normal now, don't you?

FROM 12 JAN

Explorer Top 125

National Geographic, starts 12 January, 8pm



HAPPY 125TH BIRTHDAY to the National Geographic Society, which had exploration as its mission long before television let us all tag along. Every Saturday in 2013 will celebrate explorers, from the age when an ostentatious moustache was compulsory kit to today's researchers who look inwards as well as out. The season launches with 'Exploring New Frontiers – National Geographic At 125', which introduces explorers including director-turned-deep-sea-explorer James Cameron.

FROM 13 JAN

Ancient Aliens

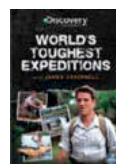
History, starts 13 January, 9pm



The pyramids prove that ET has a fine eye for triangular architecture

➔ SURELY THE MOST ambitious and comprehensive attempt to gather evidence for extra-terrestrial visitors to earth over the last 75 million years, this 16-part series takes us from dinosaurs to the deserts of modern America. What is the strange asphalt-like substance in the Egyptian pyramids? What are the mysterious creatures depicted in ancient cave paintings? You may not find any of this proof that aliens have walked among us, but you will see plenty of people on-screen who are sure they have met ET.

DVD & BLU-RAY



James Cracknell: World's Toughest Expeditions

DVD, Discovery, £12

THIS FOUR-PARTER sees the rugged Mr Cracknell recreate the harshest journeys from the golden age of exploration. He paddles a dugout canoe up the Zambezi River, sails the Southern Ocean to New Zealand, and lives as a Gold Rush pioneer in the USA.



Stephen Hawking's Grand Design

DVD, Discovery, £12

TRAGICALLY, NOT A home-improvement show based on the cosmologist's tastes in interior decor – swirling nebulae in the guest bedroom? – but a three-parter tackles the ultimate questions: Why does the Universe exist? And is there a meaning to life?



Richard Hammond's Miracles Of Nature

DVD, BBC, £13

THE *TOP GEAR* presenter reveals Nature's most astonishing adaptations and then shows how we have copied them for our own purposes. For example, cuttlefish can change colour using a technique that's been adapted for military camouflage.

FROM 21 JAN

Dark Matters

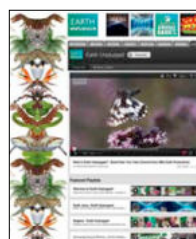
Discovery Science, starts 21 January, 10pm



NOT TO BE confused with dark matter, the mysterious stuff that makes up most of the Universe, this series looks set to give you nightmares. Sci-fi actor John Noble looks at the extremes of research, when scientists dabble with death. From head transplants to human-animal hybrids, it uses CGI to bring to life zombie research (sorry) and the invention of the electric chair.

ONLINE NOW

Earth Unplugged

www.youtube.com/earthunplugged


FEATURING BBC WORLDWIDE content made for digital audiences, Earth Unplugged is a new online natural history channel. Everything from dinosaurs to the latest discoveries can be found in short films. Cute animal babies? Creepy crawlies? Deadly beasts competing to be top dog? They're all here, along with interviews with the scientists inspired by them.



LISTEN

BBC RADIO PROGRAMMES

WITH TIMANDRA HARKNESS

JANUARY

The Physicists

BBC Radio 3, January

ANOTHER CLASSIC PHYSICS drama, this one a farce starring Samantha Bond. Three theoretical physicists who believe they are Einstein, Newton and Möbius are locked in an asylum. Then the murders begin. Expect jokes about quarks and Schrödinger's cat, a love story between a nurse and a scientist who may or may not be mad, and music from the score to *Fahrenheit 451*. And deeper themes about knowledge, power and control.

when people get arrested for tweets or Facebook posts, but it seems it can be invoked against legal claims for privacy. Do we own our virtual identity?



Be careful what you tweet!

13 JANUARY

Copenhagen

BBC Radio 3, 13 January

IN 1941 PHYSICIST Werner Heisenberg travelled to occupied Copenhagen to meet his one-time mentor and friend, Danish physicist Niels Bohr. Nobody knows what happened, but what passed between the two men may have changed the course of the Nazi's drive for nuclear weapons. This play imagines the encounter between the Bohrs and Heisenberg. Starring Benedict Cumberbatch, Simon Russell Beale and Greta Scacchi.

27 JANUARY

Living World: Red Kites

BBC Radio 4, 27 January, 6.30am

IF YOU'VE EVER looked up from a motorway and wondered what the big, fork-tailed bird above you was, you've witnessed a conservation success story in flight. This episode of the wildlife series visits County Durham, where the same Red Kites have been reintroduced to an urban landscape near Newcastle upon Tyne.

JANUARY

The Essay

BBC Radio 3, January

THE REGULAR FOOD-for-thought slot explores the ways real scientists have inspired fictional characters. We don't know yet which scientists – or which fictional characters – will appear, but we're hoping they won't include Doctor Frankenstein, Dr Strangelove or Dr No. Then again, there have been some curious personalities among real life researchers...

7 JANUARY

Do I Have The Right To Be Forgotten?

BBC Radio 4, 7 January, 8pm

IN THE SOCIAL media age it's only too easy to post your private life into the public domain, or to have others post it without even asking. But it's not so easy to wipe it clean, as Emma Barnett finds out in this documentary. Freedom of speech may seem limited



TOUCH

SMARTPHONE & TABLET APPS

WITH CHRISTOPHER PHIN



Pyramids 3D

iPad, Touch Press LLP, £9.99

ON ONE HAND, an app such as this that lets you explore the tombs of the Giza Plateau is no substitute for going there and exploring in real life. But on the other, you wouldn't have world authorities guiding you round the sites if you did. It's a wonderfully immersive app that lets you not only walk round and find out about the tombs of Meresankh, Tjetu, King Khafre and more (plus some important objects) in full 3D, but is packed with then-and-now photos and reconstructions. We lost ourselves for an entire afternoon, and kept coming back!



Atlas by Collins

iPhone, iPod touch, iPad; HarperCollins; £4.99

IMAGINE A PRINCE in times gone by. He's not only given a set of accurate globes – one that shows physical features, one political boundaries, one a satellite photo of the world and so on – but also a tutor who can always answer him when he spins the globe, points to something and asks "what's this?". That's what you get with this app. Pinch to zoom, swipe to rotate – or, using the gyroscope, just move your device – and, at any time, tap a button for more on what you're looking at.



ColorRotate

iPad, IDEA, £2.99

THIS IS OSTENSIBLY a tool for creative types. It allows you to create palettes of colours by importing a photograph and picking out colours from it before tweaking them. You can also define a master colour and then have the app create a configurable complementary group of colours, before manipulating them in an interactive 3D space. Your palettes can be shared in various ways, including directly with Photoshop. It's a fascinating toy if you're interested in colour and the relationships between different hues, shades and tints.

CHRISTOPHER PHIN is the editor of **TAP!** magazine



PLAY

CONSOLE & COMPUTER GAMES
WITH NEON KELLY



DmC: Devil May Cry

PS3, Xbox 360, Capcom, £39.99

DMC: DEVIL MAY Cry features a boss fight against a monstrous parody of Bill O'Reilly, the right wing pundit from Fox News. That alone should be enough to tickle your curiosity, but here's the hard sell: this is a reboot of one of the most influential action franchises in modern gaming. You play as Dante, a baby-faced demon hunter with a penchant for pistols and swords, battling through the nightmarish Limbo City - a possessed town that has a mind of its own. Strange but achingly stylish.



The Unfinished Swan

PS3 download, SCE, £9.99

CAN VIDEO GAMES be art? *The Unfinished Swan* fans the flames of that debate. This is a brief, but original game that initially deposits you in a blank white landscape. The motion-controlled PlayStation Move remote lets you throw out black blobs that splash against your surroundings, causing scenery to pop into view. You inch forward into the void, make like Jackson Pollock, and then watch as the world reveals itself. It's a provocative concept, though the actual 'game' is undernourished.



Strike Suit Zero

PC, Born Ready Games, price TBC

WE ALL KNOW that space is a vacuum, that it's impossible for starships to go 'boom'. But we're all happy to suspend our disbelief in favour of big explosions - an arrangement that *Strike Suit Zero* clearly understands. This game wants to rekindle our love for epic space battles, with controls that favour arcade carnage over straight-faced simulation. There are plenty of massive craft to blast apart, and for extra giggles you can turn your own ship into a flying robot mech. Fun indeed.



EDITOR'S
CHOICE

Take control of Studio Ghibli's wonderfully animated characters

Ni No Kuni

PS3, Namco Bandai, £39.99



➔ HAVE YOU SEEN *Spirited Away*, *Howl's Moving Castle* or *My Neighbour Totoro*? If you haven't, you

should really try to rectify that situation. They're wonderful, heartbreakingly sweet films; the kind that leave you feeling like you've just swallowed a slice of sunshine pie. They're the work of Studio Ghibli, the Oscar-winning animation studio which stands as Japan's rough equivalent to Pixar. And *Ni No Kuni* is its first video game, developed in partnership with games studio Level-5.

Without this pre-ambles there's a good chance that you'd read the game's title, frown at the seemingly meaningless quartet of syllables, and then move on to something else. 'Ni No Kuni' roughly translates as 'Second World', but to be honest that barely does a better job of

selling the experience on offer. No, to understand the game's appeal, you need to see it in motion, to see the animation come to life under your control.

The game's beauty cannot be overstated. As Japanese role playing games go this does little to rock the boat, offering the usual mix of exploration, turn-based battles, and character-driven storytelling. But its sublime child-like art direction, graphics and animation give even the most familiar ingredients a new lease of life. There's a subterranean steampunk city, for example, and though we've seen this kind of location a dozen times before, it feels fresh because it's a Studio Ghibli subterranean steampunk city. And because it's populated with sinister anthropomorphic pigs.

You'll care about the central story - a young boy explores a strange land in search for his mother, who gave her life to save him. But *Ni No Kuni*'s world is so charming in its details, there's pleasure to be found in even the quietest moments - when you're simply pottering around on the map screen, for instance.

If you're looking for an antidote to the chilly come-down of New Year, this is the perfect tonic.



READ

THE LATEST SCIENCE BOOKS REVIEWED

H Hardback **P** Paperback



The World Until Yesterday

What Can We Learn From Traditional Societies?

Jared Diamond

Allen Lane **H** £22.49

AS RECENTLY AS 10,000 years ago all humans lived as hunter-gatherers – we hunted and foraged for food and constructed belongings from things acquired from our surroundings. In parts of Africa, New Guinea and South America, some still live in this way. Jared Diamond wonders if we can learn anything from these people who populated the world, as he puts it, up ‘until yesterday’.

It is an enticing prospect – hunter-gatherers present us practices for looking after the elderly, rearing children, mediating disputes and punishing bad behaviour, and they suffer far less from diseases such as diabetes and hypertension that are prevalent in modern life.

But don't be mistaken, Diamond is not of the ilk to see our ancestors as noble savages living in harmony with nature in a peaceful arcadia. Far from it. Humans evolved in Africa 160,000 to 200,000 years ago and there is good reason to believe that our history has been one of living in small

tribal societies that were continually at war with one another, and routinely practiced slavery, the stealing of children and women, sorcery, drug use and cannibalism.

So, one must wade carefully through the great diversity of our past. Happily, Diamond is well equipped for his task, with vast experience of working in New Guinea and a seemingly endless grasp of facts about language and culture. In one example, Diamond learns to admire how traditional people are often far more aware of rare but potentially dangerous risks in their environment than people from the developed world. He advises that all of us acquire what he calls ‘constructive paranoia’ in our daily lives.

It is material such as this that makes *The World Until Yesterday* an enjoyable and thought-provoking read.



PROFESSOR MARK PAGEL is an evolutionary biologist and author of *Wired For Culture*

MEET THE AUTHOR



Jared Diamond

Why did you write this book?

Because it's the most fascinating thing that I could think of to write about! I have 50 years' experience of living in New Guinea and I realised that it's going to be my most personal book. I've written four other books for the public, but this will be the one that has most of my own experiences. It'll also be my most practical book – it's chock-full of practical stuff about how to lead our lives.

Which part of the book was most challenging to write?

One of my two chapters about dangers is a personal chapter. It illustrates risks by going through three incidents in New Guinea where I nearly got killed. It was uncomfortable to have to relive those experiences and to have to remember how close I came to dying and... how stupid I was at the time.

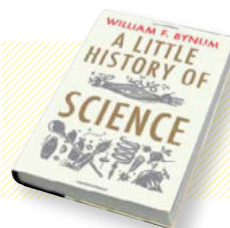
Have your experiences with tribal societies affected the way you live?

Oh, absolutely. First of all, they've affected my attitude towards danger and taking risk. I drive many of my American friends crazy with my attitude towards risks, but I've just seen a lot more about the consequences of risky behaviour in New Guinea than most Americans.

Another thing is bringing up children. My wife and I had twin sons 25 years ago and the way I brought them up has been really influenced by how I've seen New Guineans bringing up their children. New Guinean children quickly become socialised, independent, self-confident and autonomous, and I've tried to help my kids in that direction.

MORE ON THE PODCAST

Listen to the full interview with Jared Diamond on the podcast at sciencefocus.com/podcasts



A Little History Of Science

William Bynum

Yale £14.99

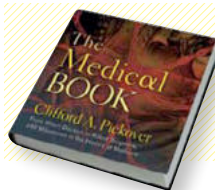
THIS IS A thoughtful, elegantly presented volume with the younger reader in mind, although it's an inspiring reminder to anyone of our extraordinary journey from ignorance to knowledge.

As a straight history of science it covers all the stories you'd expect. Concise chapters lead us gently through ancient India and China, to Greece (Aristotle and Eratosthenes measuring the circumference of the Earth), Galileo, Newton and Einstein. It goes on to cover the emergence of chemistry, medicine, Darwin, genetics and cosmology, up to the present day and the digital revolution. It has a comfortingly nostalgic tone to the writing, never patronising but always encouraging you to think and question the story's context and significance. Each chapter is headed with a beautifully simple, monochrome block-print style illustration that encapsulates its themes.

At its heart is the reminder of what science is, why we do it, and that science is an ongoing process. Above all, it's a book with a simple message that can be summed up by the opening line: 'Science is special. It's the best way of finding out about the world and everything in it – and that includes us.'



DALLAS CAMPBELL presents *Supersized Earth* on BBC One



The Medical Book

From Witch Doctors To Robot Surgeons,
250 Milestones In The History Of Medicine

Clifford A. Pickover

Sterling £19.99

STYLISH AND WELL laid out, this is a comprehensive history of medicine, but one that glosses over the fine detail. For example British surgeon Joseph Lister gets credited with 'convincing medical professionals of the need for using antiseptics'. This summary glosses over the fact that Lister's innovation, using carbolic spray on wounds, probably did as much harm as good and his wards were notoriously filthy. Lister kept few records and those that he did suggest that in the early days his success rates were no better than many of his colleagues', and significantly worse than those who were keener on maintaining higher levels of cleanliness. No wonder his medical contemporaries were unimpressed.

Similarly, Dr Alexander Fleming gets the credit for 'discovering the world's first antibiotic', but no mention is made of the fact that having made some initial observations he did little with them.

This book is adequate if you want an overview, but if you are looking for revelations you will need to go elsewhere.



Michael Mosley is a writer, doctor and BBC science presenter



Inside The Centre

The Life Of J Robert Oppenheimer

Ray Monk

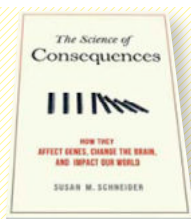
Jonathan Cape £30

OFTEN DESCRIBED AS 'the father of the atomic bomb', the American physicist J Robert Oppenheimer is best-known for directing the scientific effort behind the Manhattan Project, which built the first nuclear weapons. While very smart (he did key work on neutron stars and black holes), 'Oppie' was no genius, but it took an unusual personality to corral the greatest concentration of brain-power ever assembled to produce a successful conclusion. It took an even more singular one to later declare himself and his colleagues as scientific sinners, and suggest they all share their secrets with their Soviet counterparts. Not surprisingly, Oppie provoked deep suspicion among his masters and his post-war persecution, decline and demise at the age of just 62 should make for an engrossing biography.

Sadly, not even a writer as accomplished as Monk can fathom Oppie's mind, or rid him of his reputation as a sanctimonious smart-aleck. Anyone who, like me, comes to this huge new biography hoping for fresh insights into Oppie's science, mind and loyalties is likely to be disappointed. He remains as coldly enigmatic as ever.



ROBERT MATTHEWS is a visiting reader in science at Aston University



The Science Of Consequences

How They Affect Genes, Change The Brain, And Impact Our World

Susan M. Schneider

Prometheus £18.99

THIS IS AN overly ambitious book that tries to cover every facet of behaviour to explain outcomes. It is jam-packed with nuggets of amazing findings, but like an overgrown intellectual jungle, the path suddenly twists, jerks and forks unexpectedly. It runs the entire spectrum of the living world from flatworms to humans, covering the full range of behaviours from instincts up to morality.

Having examined basic behavioural learning early on, the book concludes that consequences on a global scale are unpredictable. The pace made this reader's head spin and even though much of the

material was familiar, the transitions left me breathless.

However, there were moments revealing the author's expertise to make complex ideas simple. The discussion of heritability was a succinct, clear explanation; the rest of the book could have benefited from similar respites. Personal touches helped, but there were too many asides. Less content covered more thoroughly would have made for a better read.



PROF BRUCE HOOD is the author of *The Self Illusion*

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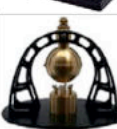
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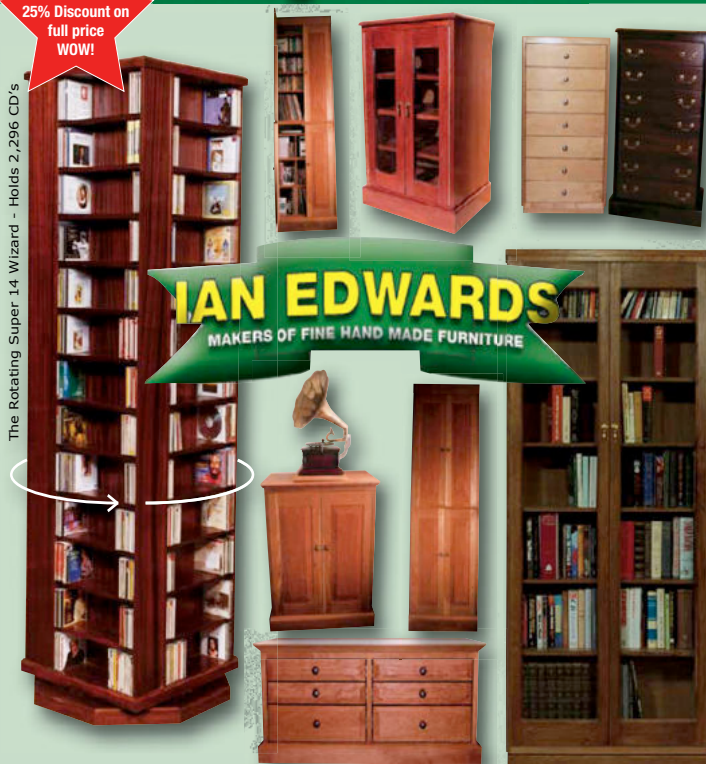
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(March 2011)

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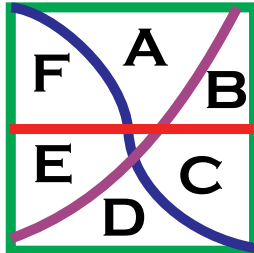
MINDGAMES



Pit your wits against these brainteasers by David J Bodycombe, question-setter for BBC Four's *Only Connect*

PRIZE PUZZLE

Given that each line bisects the square into equal areas, which area is larger: A or D?



WIN! RICHARD HAMMOND'S MIRACLES OF NATURE

The first five correct entries win a copy of *Richard Hammond's Miracles Of Nature* on DVD (BBC, £13).

Post your entry, marked 'Prize Puzzle 250', to: Focus magazine, PO Box 501, Leicester, LE94 0AA, to arrive by 5pm on 10 January 2013. We regret that we cannot accept email entries for this competition. See sciencefocus.com/winners for a list of previous winners and solutions.



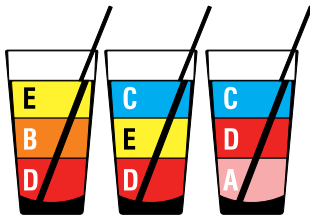
See bottom of p96 for terms and conditions. Congratulations to RF Tindell (Cambridge), David Thompson (Guernsey), Kevin Ward (Stroud) and Peter Haworth (Bristol) who all answered the October issue's Prize Puzzle correctly to each win a copy of *A Bee In A Cathedral*.

Q1

Many skyscrapers around the world miss out 'unlucky' numbers for floors like 4 or 13. But why does the Trump Tower in Manhattan miss out 10 floors in its numbering?

Q2

Order the colourful liquids in these, layered cocktails from the least to the most dense:



Q3

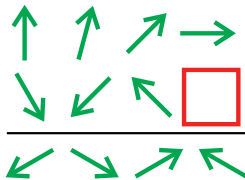
Begin with a foreign woman. Remove one letter each time to obtain: a woman generally; the first man; a female; a father. What are these five words?

Q4

If green is primary, white is local, brown is tourist and yellow is temporary, what are blue and black?

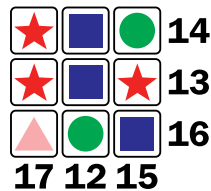
Q5

Which of the four arrows below the line should go in the box?



Q6

Each shape represents a different whole number. Which total is wrong? What should it be?



Q7

If you played standard draw poker with three cards in your hand instead of five, what would the hand rankings be from highest to lowest? Note that things like 'Two pair' would be omitted.

Q8

In this Nurikabe puzzle, you must shade in cells representing a river that envelops a number of white 'islands'. The given numbers tell you how large each island is, in squares. There is only one number on each island, and you cannot add your own numbers. Islands don't touch, except possibly at corners. The 'stream' must be continuous and fully connected - ie it is possible to travel, via horizontal and vertical moves, from one part of the stream to any other. The stream is only one square wide - this means that you can never have a 2x2 square full of stream spaces.

5		3		2			1		
							2		2
				2					
						5		1	
	1		3						
					1				
2		2							
		2			2		2		4

SOLUTIONS

- Q1) Because a 68-floor building sounds more impressive than 58 floors and, more importantly, can charge higher penthouse rents. Several other Donald Trump developments use the same trick.
 Q2) C, E, B, D, A (denser).
 Q3) MADAME, MADAM, ADAM, DAM (female animal), DA (short for 'Dad').
 Q4) Blue is for motorways; black is for HGVs (background colours on UK road signs).
 Q5) The third arrow. The arrow rotates by 15, 30, 45, 60, 75, 90 and 105 degrees at each stage.
 Q6) The 15 should be a 14. Square=3, Star=5, Circle=6, Triangle=7.
 Q7) Straight Flush (48 possibilities), Three of a kind (52), Straight (720), Flush (1096), One Pair (3744) then High Card.
 Q8) See illustration on p96.

QUICK QUIZ

How much do you know about metals?

Q1

Which is the only metal that's liquid at room temperature?

- a) Potassium
- b) Mercury
- c) Lithium

Q2

Which precious metal has the chemical symbol Ag?

- a) Silver
- b) Gold
- c) Platinum

Q3

Which scientist hasn't had a synthetic metal named after them?

- a) Albert Einstein
- b) Dmitri Mendeleev
- c) Charles Darwin

Q4

Rust is formed when which metal is oxidised?

- a) Aluminium
- b) Tin
- c) Iron

Q5

Which of these is not one of the alkali metals?

- a) Sodium
- b) Magnesium
- c) Caesium

Q6

6) What is the approximate melting point of tungsten, the highest of any pure metal?

- a) 1,400°C
- b) 2,400°C
- c) 3,400°C

Q7

Bronze is an alloy consisting mostly of which metal?

- a) Copper
- b) Lead
- c) Zinc

ANSWERS:

1b, 2a, 3c, 4c, 5b, 6c, 7a

YOU ARE:

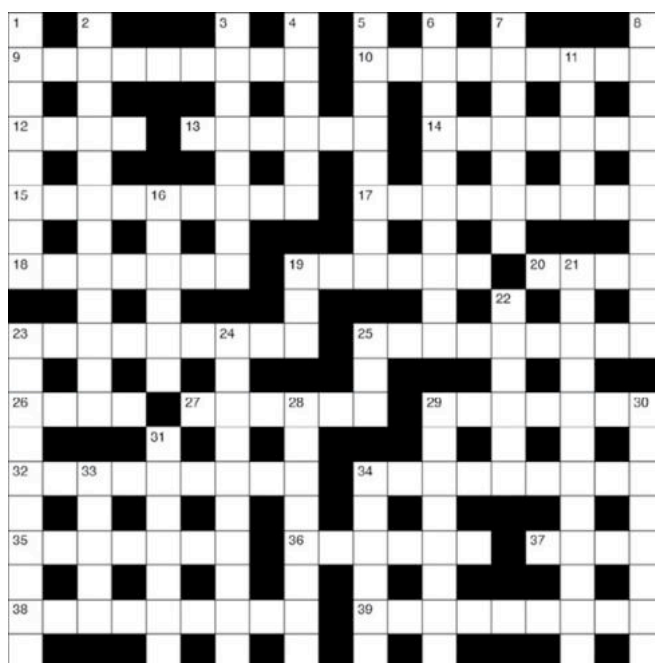
0-3 Fool's gold

4-5 As good as gold

6-7 A gold mine of information

FOCUS CROSSWORD No 146

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ACROSS

- 9 Quietly heat shop using fertiliser (9)
- 10 Nice rent review has minute rise (9)
- 12 Lied about not being in gear (4)
- 13 Marsupial found at place of shelter first (6)
- 14 Style of string playing that's a lot more unusual (7)
- 15 Source of energy might motivate wolves (5,4)
- 17 Semiconductor may possibly incur hope (9)
- 18 Belly gives terribly bad sign (7)
- 19 Endless perfume I caught was beautiful (6)
- 20 School yet to deal with inflammation (4)
- 23 Sells William a turtle (9)
- 25 Tower provides accommodation by a river (9)
- 26 Name for a variety of corundum (4)
- 27 Hen ate form of fuel (6)
- 29 Laugh as cadet runs round terminal (7)
- 32 Shark rode off to get unknown competitor (4,5)
- 34 Grey scoop turned out to be a balanced item (9)
- 35 Attempts to reach the borders of Italian port (7)
- 36 Moving so near ground (6)
- 37 Went off the amphibian (4)
- 38 Our case so different from one plant family (9)
- 39 Early stage affected more by rep (3-6)

DOWN

- 1 Leave ape to cultivate vegetable (5,3)
- 2 Net created by spiders internationally (5,4,3)
- 3 Fabric means I can roam around (8)
- 4 Antelope broke out with energy (6)
- 5 I would return to position of remoteness (8)
- 6 Travel when you've turned green (10)
- 7 Complete mess without quiet way to keep in touch (7)
- 8 Pressure to produce pervasive feeling (10)
- 11 Old church pursued record for a long time (5)
- 16 Artist has some difficulty with branches (6)
- 19 Thus left for a day on Mars (3)
- 21 Force gnome trio to attempt some mathematics (12)
- 22 Note performance by America that's prickly (6)
- 23 Passed on that woman's dietary plan (10)
- 24 Transformed into freer new protein (10)
- 25 Copper gets point of signal (3)
- 28 Main user developed dangerous condition (8)
- 29 Fish around river were carried and consumed (8)
- 30 Choose fellow to charge (8)
- 31 Doctors remove Scotsman from science (7)
- 33 Miser sent to coronation site (5)
- 34 Spirit makes old king send father back and forth (6)

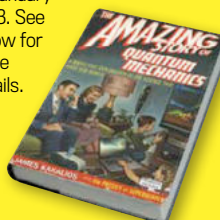
SOLUTION TO CROSSWORD No 143

Charles Parry, Keith Hodgson, AP Coniam, S Millard and David Cockrell solved issue 247's puzzle and each receive a copy of *Curiosity - Did God Create The Universe?* on DVD.



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The first five correct solutions drawn will each win a copy of *The Amazing Story Of Quantum Mechanics* by James Kakalios (Duckworth, £9.99). Entries must be received by 5pm on 10 January 2013. See below for more details.



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INTO THE FUTURE

STEPHEN BAXTER

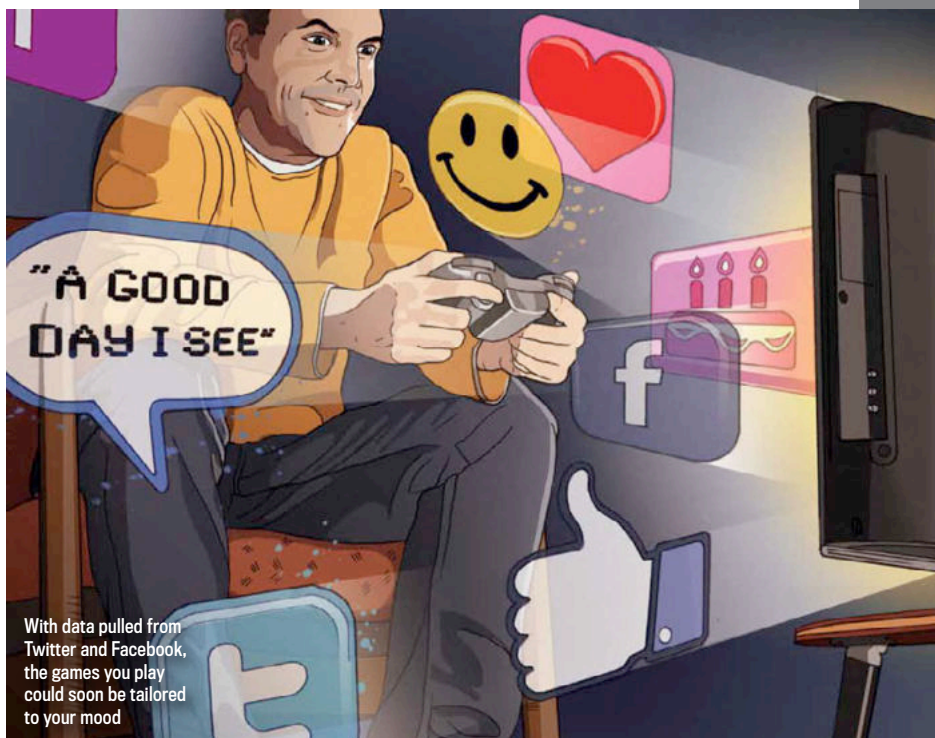
AS GAMING HAS become a massive industry that attracts huge investment and intense competition, there are a lot of bright ideas around concerning its future. It's easy to imagine a game becoming more 'real' through better graphics and sound, perhaps even using immersive virtual reality where you feel as if you have physically entered its world. But what about games becoming more realistic emotionally?

The social networks of the real world are delivering masses of new data on how we interact with each other, and games are starting to exploit that data for added realism. An experimental game about the social lives of high school students called *Prom Week*, developed by a team at the University of California, Santa Cruz, contains rules to model the characters' social interactions – just as a good game should contain rules mirroring laws of physics such as gravity and momentum. The characters have networks of contacts, feelings such as hidden likes or dislikes for each other, and quirky personality traits.

But how about a game that reacts to you as an individual? Peter Molyneux, a British games developer with a studio called 22Cans, intends to mine the data you 'leak' about yourself in social media and feed that back into the game. If you feel happy or sad today, based on an analysis of this morning's tweets, characters in the game will react to you accordingly – just like people in the real world.

Mathematicians, meanwhile, are becoming intrigued by games' computational complexity. Many well-known games, such as the Mario series, are equivalent to what is known as 'NP-hard' problems, which essentially means it's very difficult to work out whether a player can reach the end. This feature makes for an interesting game, but real-world 'NP-hard' problems, such as the 'travelling salesman' problem about finding the shortest route between a series of points, are of interest in fields like logistics, with a lot of money often at stake. Algorithms deliver approximate solutions to such problems. In theory, though, you could convert a real-world problem into a mathematically equivalent game and let thousands of gamers play their way to solutions, in a kind of crowd-sourcing exercise.

What about the future of games design? As artificial intelligence (AI) advances, interesting new possibilities are opening up. At the annual IEEE Conference on Computational Intelligence and Games, a prize is awarded for the most convincing AI-controlled character in a



“In theory, you could convert a real-world problem into a mathematically equivalent game and let thousands of gamers play their way to solutions”

video game called *Unreal Tournament*. So far the 'bots' have failed to achieve the standards set to win the big prizes and haven't been able to beat real players. Perhaps reassuringly, the judges say they lack the sheer relentlessness of their human-controlled rivals... so far.

There have even been experiments in letting AIs design games. Computer scientists at Imperial College London have devised a software suite called Angelina that creates Space Invaders-type games using a stock of rules and settings. Angelina 'plays' its prototype games through several times, as if they were being played by humans, so they can be tried out for difficulty and interest. For now these games still need human designers to complete them, but already the designers believe they could generate a game good enough to upload to the Apple app store every 12 hours.

Thanks to Moore's Law, which predicts an exponential growth in computer power, AIs are only going to get smarter – eventually, perhaps, smarter than us. You could easily imagine a nightmarish future in which we humans are hypnotised by an endless stream of totally engaging, individually personalised games devised by super-intelligent computers, while the results of our lifetimes of

playing are mined for solutions to intractable mathematical problems. You probably ought to make sure you can always reach your games console's Off switch... ■

STEPHEN BAXTER is a science fiction writer whose books include the *Destiny's Child* series and *The Science Of Avatar*

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